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The Status of Virginia's Public Oyster Resource 2003

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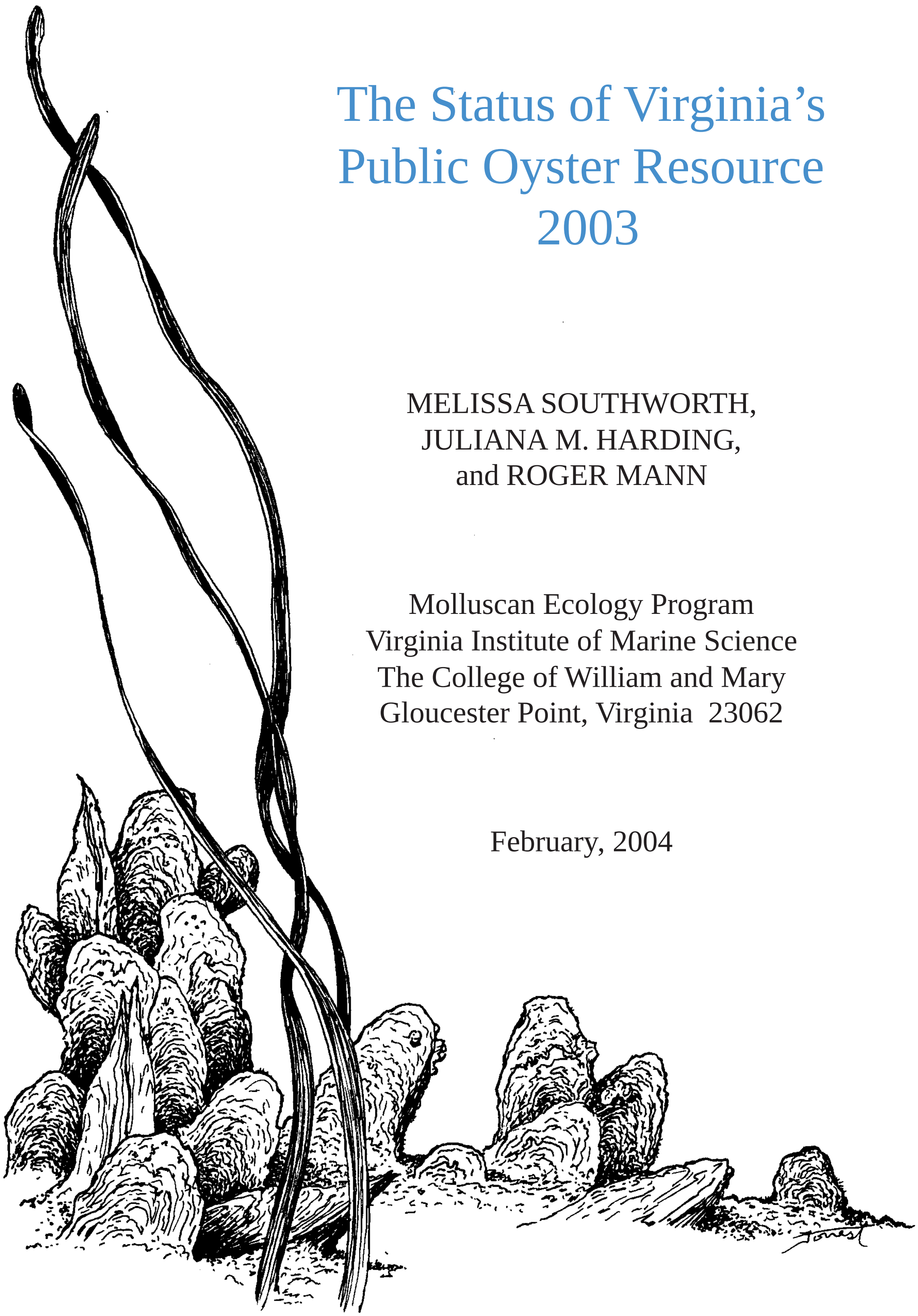

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Part I.

Oyster Spatfall In Virginia During 2003

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors the recruitment activity of the Eastern oyster, *Crassostrea virginica* (Gmelin 1791), annually from June through October, by deploying spatfall (settlement of larval oysters or spat) collectors (shellstrings) at various stations throughout Virginia's western Chesapeake Bay tributaries. The survey provides an estimate of a particular area's potential for receiving a "strike" or settlement (set) of oysters on the bottom and helps describe the timing of settlement events. Information obtained from this monitoring effort is added to a database that provides an overview of long-term spatfall trends in the lower Chesapeake Bay and contributes to the assessment of the current oyster resource condition and the general health of the Bay system. These data are also valuable to parties interested in potential timing and location of shell plantings.

Results from spatfall monitoring reflect the abundance of ready-to-settle oyster larvae in an area, and thus, provide an index of both oyster population reproduction and development and survival of larvae to the settlement stage in an estuary. Environmental factors affecting these physiological activities may cause seasonal and annual fluctuations in spatfall, which are evident in the data.

Data from spatfall monitoring also serve as an indicator of potential oyster recruitment into a particular estuary. Settlement and subsequent survival of spat on bottom cultch (shell) is affected by many factors, including physical and chemical environmental conditions, the physiological condition of the larvae when they settle, predators, disease, and the timing of these factors. Abundance and condition of bottom cultch (shell available for larvae to settle on) also affects settlement and survival of spat on the bottom. Therefore, settlement on shellstrings may not directly correspond with recruitment on bottom cultch at all times or places. Under most circumstances, however, the relationship between settlement on shellstrings and bottom cultch is expected to be commensurate.

This report summarizes data collected during the 2003 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2003 was monitored from the first week of June through the first week of October in the James, Piankatank and Great Wicomico Rivers. However, due to poor weather and Hurricane Isabel entering the Bay on September 18th, there was a two to three week period in September when we were unable to check our stations. Spatfall stations included eight historical sites in the James River, three historical and five new sites in the Piankatank River, and five historical and four new sites in the Great Wicomico River (Figure S1). In this report, historical sites refer to those that have been monitored yearly for at least the past fifteen years whereas "new" sites are stations that were added during 1998 to monitor the effects of replenishment efforts by the Commonwealth of Virginia. The new sites in both the Piankatank and Great Wicomico Rivers correspond to those sites that were considered "new" in the 1998 survey. Since 1993, the Virginia Marine Resources Commission (VMRC) has built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay, as well as on the Eastern Shore inshore of Fisherman's Island, Pungoteague Creek and Pocomoke and Tangier Sounds (Figure S2). The change in the number and location of shellstring sites during 1998 was implemented to provide a means of quantitatively monitoring oyster spatfall around these reefs. In particular, broodstock oysters were planted on a reef in the Great Wicomico River during winter 1996 and on reefs in the Piankatank and Great Wicomico

Rivers during winter 1997. The increase in the number of shellstring sites during 1998 in the two rivers coincide with areas of new shell plantings in spring, 1998 and provide a means of monitoring the reproductive activity of planted broodstock on the artificial oyster reefs. Since 1998, many of the reefs and bottom sites in the Piankatank and Great Wicomico Rivers have received both broodstock oysters on the reef and shell plants on the bottom surrounding the reefs. During 2003 (spring and early summer) shells were planted on Stove Point, Bland Point, Palace Bar, and Ginney Point in the Piankatank River and on Shell Bar and Rogue Point in the Great Wicomico River. There were no broodstock planted on any of the reefs in either the Piankatank or Great Wicomico Rivers during 2003 (see Figures S1 and S2 for specific locations in each river).

Oyster shellstrings were used to monitor oyster spatfall. A shellstring consists of twelve oyster shells of similar size (about 76 mm, (3-in) in length) drilled through the center and strung (inside of shell facing substrate) on heavy gauge wire (Figure S3). Throughout the monitoring period, shellstrings were deployed approximately 0.5 m (18-in) off the bottom at each station. Shellstrings were usually replaced after a one-week exposure and the number of spat that attached to the smooth underside of the middle ten shells was counted under a dissecting microscope. To obtain the mean number of spat shell^{-1} for the corresponding time interval, the total number of spat observed was divided by the number of shells examined (ten shells in most cases).

Although shellstring collectors at most stations were deployed for seven-day periods, there were some weather related deviations such that shellstring deployment periods ranged from six to fourteen days. These periods did not always coincide among the different rivers and areas monitored. Therefore, spat counts for different deployment dates and periods were standardized to correspond to the 7-day standard periods specified in Table 1. Standardized spat shell^{-1} (S) was computed using the formula:

$$S = \text{spat shell}^{-1} / \text{weeks } (W)$$

where W = number of days deployed / 7. Standardized weekly periods allow comparison of spatfall trends over the course of the season between the various stations in a river as well as between data for different years.

The cumulative spatfall for each station was computed by adding the standardized weekly values of spat shell^{-1} for the entire season. This value represents the average number of spat that would fall on any given shell if allowed to remain at that station for the entire sampling season. Spat shell^{-1} / week values were categorized for comparison purposes as follows: 0.10-1.00, light; 1.01-10.00, moderate; and 10.01 or more, heavy. Unqualified references to diseases in this text imply diseases caused by *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (*Perkinsus* or Dermo).

Water temperature and salinity measurements were taken at all stations. Water was collected each week from approximately 0.5 m off the bottom with a Niskin bottle. Temperature (degrees C) was then measured with an alcohol thermometer and salinity (in ppt, or parts per thousand) was measured with a hand-held refractometer.

RESULTS

Spatfall on shellstring collectors for 2003 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement for the past sixteen years at the historical stations in all three river systems and the past six years for the new stations in the Piankatank and Great Wicomico Rivers. Unless otherwise specified, the information presented below refers to those two tables. In this report the term peak is used to define the period when there was a noticeable increase in settlement throughout a river system. When comparing 2003 data with historical data in the James River, all eight stations were used. Due to the addition of new sites during 1998 in the Piankatank and Great Wicomico Rivers, any comparison made to historical data could not include data from all of the sites sampled during 2003. Comparisons were made over the past five years for the new sites whereas the historical sites include ten to fifteen years of data. Historical sites in the Piankatank are Burton Point, Ginney Point, and Palace Bar. Historical sites in the Great Wicomico include Fleet Point, Glebe Point, Haynie Point, Hudnall, and Whaley's East (Cranes Creek in data reports prior to 1997).

James River

Oyster settlement in the James River was first observed during the week of August 19 at six out of the eight stations monitored (Table S1). Settlement continued at Wreck Shoal and Dry Shoal from then until the week of September 2 and was intermittent for the rest of the season at the other six stations. Hurricane Isabel prevented us from collecting the shellstrings for most of September. Thus, it is not possible to determine if the peak in settlement that began in mid August (Figure S4) continued until the end of the season, i.e. into late September.

Overall settlement in the James River during 2003 was low with cumulative spat shell^{-1} / week ranging from a low of 0 at Horsehead to a high of 1.3 at Wreck Shoal. In years past, settlement in the James tended to be higher at the more southern downriver stations when compared with the more northern upriver stations (Figure S1 and Table S2). However, for the past five years, observed settlement has been more evenly dispersed throughout the river. Settlement during 2003 while low throughout the river, had a slightly higher number of spat at the mid to downriver stations.

Settlement in the James River during 2003 showed a relatively large decrease from the previous year (2002) as well as from the previous five, ten, and fifteen-year means at all stations monitored (Table S2). Spatfall during 2003 was the lowest seen in the past fifteen years at all of the stations except Wreck Shoal (Figure S5), which was the fourth lowest in the past fifteen years.

Average river water temperatures reached a maximum in early July (29.0°C: Figure S6A). Water temperatures throughout the 2003 sampling season were similar to the previous five and ten-year means until September (Figure S6A). Temperature toward the end of the 2003 sampling season was around 5 to 6°C higher than the previous five and ten-year means. Salinity on the other hand was an average of 5 to 6 ppt lower than the previous five and ten-year means throughout the entire 2003 sampling season (Figure S6B). There was a 7 to 8 ppt salinity difference between Deep Water Shoal (the most upriver station) and Day's Point (the most downriver station: Figure S1). There was a period of several weeks in mid to late June when salinity remained below 10 ppt at all eight stations and was zero at both Horsehead and Deep Water Shoal.

Piankatank River

Settlement in the Piankatank River was first observed during the week of August 5 at five out of the eight stations monitored (Table S1). There was no further settlement after that week until early September (Figure S7). Overall settlement was low throughout the entire river system. At most stations, settlement occurred during a single week, either the first week of August or the first week of September (Figure S7).

Cumulative spat shell^{-1} / week for the year ranged from a low of 0.05 at Palace Bar to a high of 0.2 at Ginney Point and Heron Rock.

Spatfall during 2003 showed a large decrease compared with 2002 at all stations monitored (Table S2: Figure S8 and S9). At the historical stations, settlement was substantially lower than the previous five, ten, and fifteen-year means. Spatfall was the lowest recorded in any one year over the past fifteen years except 1997, when there was total recruitment failure at two out of the three historical stations monitored. Settlement at the other five (new) stations was lower than the previous five-year mean and was the lowest observed since monitoring began at those sites in 1998.

The average Piankatank River water temperature ranged from 20 to 28°C throughout the sampling period, reaching a maximum in July and August.

Water temperature was similar to the average temperatures previously recorded in the river until the very end of the sampling season at which time it was approximately 5°C warmer (Figure S10A). Salinity ranged from 11 to 15 ppt throughout the sampling period. Similar to the James River, salinity in the Piankatank River was lower than the previous five and ten-year means, averaging a 2 to 3 ppt difference throughout the sampling season (Figure S10B). The difference recorded between Wilton Creek (the most upriver station) and Burton Point (the most downriver station: Figure S1) during 2003 was approximately 1 to 2 ppt.

Great Wicomico River

Settlement in the Great Wicomico River during 2003 began at Shell Bar during the week of July 29, at Whaley's East during the week of August 12, and at all other sites the week of August 19. Settlement continued for several weeks at all sites, with the majority of spatfall occurring in late August (Figure S11). Overall settlement in the Great Wicomico River was moderate during 2003, especially when compared with that observed in the James and Piankatank Rivers.

Cumulative spat shell^{-1} / week for the year ranged from a low of 0.35 at Fleet Point to a high of 7.0 at Rogue Point. As has been observed in the past, settlement at the two stations downriver of Sandy Point, Whaley's East and Fleet Point was lower than that observed in the rest of the river. Settlement during 2003 was lower than the previous year (2002) at all of the stations sampled (Table S2: Figures S9 and S12). Settlement was lower during 2003 than the previous five-year mean at all stations sampled except Rogue Point and lower than both the ten and fifteen-year means at all five historical stations, with the exception of Whaley's East, which showed no change when compared with the ten-year mean (Table S2). The pattern of an increase in spatfall as one moves upriver was once again observed in the Great Wicomico, with the highest spatfall numbers occurring at Glebe Point and Rogue Point (the two most upriver stations).

Average river water temperatures ranged between 21 and 30°C throughout the sampling season (Figure S13A). Water temperature reached a maximum in mid to late August. Given the lack of historical data for the Great Wicomico River, temperature and salinity during 2003 could only be compared with the previous five-year mean instead of the five and ten-year mean as it was in the James and Piankatank Rivers. Except for small deviations at the end of the sampling season, water temperature was similar to the previous five-year mean (Figure S13A). As in the James and Piankatank Rivers however, salinity was lower than normal throughout the sampling season. Prior to August, there was approximately a 2 ppt difference between 2003 numbers and the previous five year mean. Beginning in early August, that difference jumped to a 3 to 4 ppt difference that lasted for the remainder of the sampling period (Figure S13B). There was a 2 to 3 ppt difference in salinity between the most upriver station (Glebe Point) and the most downriver station (Fleet Point: Figure S1) throughout most the sampling season.

DISCUSSION

Oyster spatfall during 2003 was among the lowest observed over the past fifteen years in the James and Piankatank Rivers. With the exception of parts of the James River in 1993 and to some extent the Great Wicomico River in 1997 and 2002 and the Piankatank River in 1999, low spatfall has been common in Virginia since 1991. While settlement during 2003 in the Great Wicomico River was higher than that observed in the other two river systems, spatfall was still lower than the previous five-year mean (1998-2002) at all 25 sites monitored, except Rogue Point in the Great Wicomico River. Oyster settlement was also lower than both the ten and fifteen-year means (1993 2002; 1988-2002) at all sites during 2003 (Table S2).

Overall oyster settlement in the James and Piankatank River systems was among the lowest observed over the past fifteen years of monitoring. Increased rainfall, which caused depressed salinity conditions throughout most of

2003 (VIMS Ferry Pier Data), may have played a very important role in all aspects affecting oyster settlement. This is in direct contrast to what was observed during 2002, a particularly dry and therefore high saline year in the Chesapeake Bay. In a study in the upper Chesapeake Bay, 21% of the variation in spatfall over a forty-year period was explained by a positive correlation with cumulative excess salinity (Ulanowicz, et al., 1980). Therefore, it would stand to reason that extreme rainfall (and hence decreased salinity) would result in decreased larval production and subsequent spatfall. Factors such as gametogenesis or fecundity, larval survival and growth in the plankton, quantity and quality of food, and success of metamorphosis are all affected by salinity, and in turn could have had an effect on both the timing and size of oyster settlement during 2003.

While the relationship between salinity and gametogenesis and fecundity is not well described in the literature we can make some general observations. Butler (1949) found that oysters in lower salinity (< 6 ppt) tended to mature later than those in higher salinities. In the lower salinity animals there was only one seasonal peak in spawning that occurred later in the summer as opposed to the two peaks observed in the higher salinity animals. This effect would be especially apparent in an area like the upper James River where salinities remained relatively low, reaching zero several times throughout the spawning period of 2003. If the salinity in these areas remained lower than normal for a majority of the year as was observed, then oysters in the upper James would be less able to contribute than in the higher salinity years, like 2002, (i.e. only one peak in recruitment as opposed to two). Loosanoff (1952) showed that prolonged exposure (2 weeks) to less than 5 ppt waters caused even ripe gonads to disintegrate and while fertilization did occur; development of the embryos did not progress far. Salinity may also have a direct effect on fecundity. Mann et al. (1994) found fecundity varied significantly over a three-year period and observed reduction in fecundity was correlated with declining salinities. Perhaps with the lower than normal salinity observed during 2003, the broodstock throughout the lower Bay had a lowered fecundity.

Decreased salinity may also influence the quantity and quality of food available to larvae. Light and nutrients are the two major factors that limit primary productivity (Lalli and Parsons, 1995). An increase in water flow in a system can increase stratification, thereby decreasing the amount of vertical mixing that occurs. This in turn prevents the necessary nutrients from the bottom layer from being mixed into the surface layer where they need to be to be available for use by the phytoplankton. Salinity can also have an affect on the turbidity maximum, which occurs at the upper most intrusion of seawater into an estuary and is characterized by large amounts of suspended sediment and hence lower water clarity. While the turbidity maximum in the James River occurs upriver of the extant oyster beds (approximately near Jamestown Island; Figure S1), it still exerts an influence on downriver oyster populations. A decrease in salinity pushes the turbidity maximum further downriver, thus increasing the effect on downriver oyster populations. The influence of turbidity on larval feeding remains a subject of active study although heightened turbidity can be reasonably argued to have a detrimental effect on feeding conditions, and hence larval growth and survival.

Lough (1975), estimated that maximum survival of older oyster larvae (8 days) occurred at temperatures above 21°C and between 8 and 30.5 ppt and optimum survival and growth occurred above 30°C and between 18 and 35 ppt. While temperature in all three systems was within that range during 2003, salinity in the James River was well below 18 ppt for the entire season and only reached above 8 ppt in the latter half of the season. This most likely had a detrimental effect on larval survival in the James River throughout the spawning season. Salinity in the other two systems, while greater than 8 ppt for the duration of the spawning period, still never reached the optimum salinity for survival and growth.

While salinity conditions in the Piankatank and Great Wicomico Rivers were similar, the overall settlement patterns observed in the two systems were quite different. While oyster settlement during 2003 was among the lowest observed over the past fifteen years in the Piankatank River, settlement during 2003 in the Great Wicomico River was moderate when compared with other years during the last fifteen. It is unclear as to why this was the case. Both rivers have been described as small watersheds with very low run-off, which are primarily tidally influenced and act as trap-type estuaries with regards to larval retention (Andrews, 1979). Given that the watershed of the Piankatank River is almost twice as large as that of the Great Wicomico River, (http://www.chesapeakebay.net/wshed.htm) and hence experiences slightly higher run-off, perhaps the Piankatank River experienced a lower salinity during the spring months of 2003 (when maturation of the gonads begins), prior to our monitoring season. From the data obtained from the VIMS fall dredge survey (see Part II of this report) the number of oysters available to contribute to the spawning population was similar in both rivers. However, there are several oyster bars in the upper Great Wicomico River that are not sampled as part of the VIMS survey, but are included in the VMRC survey (James Wesson, VMRC, personal communication). These bars contained a relatively large number of broodstock (when compared to the other stations) and probably made a substantial contribution to the spawning stock during 2003.stages, swimming up on the flood tide and down on the ebb tide (Wood and Hargis, 1971). Haskin (1964) also demonstrated that larval swimming activity increased with an increase in salinity. Perhaps the higher than normal salinities during 2002 when larvae were present in the water column, induced the larvae to play a more active role and hence increased dispersal into the upper reaches of the James River and retention in the Piankatank and Great Wicomico Rivers.

The high settlement observed during 2002 in the Piankatank and Great Wicomico Rivers is especially encouraging in respect to replenishment efforts. Broodstock oysters had been planted on the artificial oyster reefs in winter / spring in both systems for the past four years. During 2002 however, there was no broodstock enhancement in the Piankatank and only a modest addition in the Great Wicomico mid way through the spawning season (J. Wesson, VMRC, Newport News, VA, personal communication). Despite this, both rivers had a relatively high spatfall with the majority of the spatfall in the Great Wicomico occurring prior to broodstock enhancement. This suggests that the replenishment efforts are successful especially in years with optimal environmental conditions and food supply (as was observed during 2002), which are both important to larval survival in the plankton and successful metamorphosis (Thompson et al., 1996).

Table S1: Average number of spat shell^{-1} for standardized week beginning on the date shown. "D" indicates the date deployed. "-" denotes a week when a shellstring was not collected.

STATION	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	YEAR
	154	161	168	175	182	189	196	203	210	217	224	231	238	245	252	259	266	273	TOTAL
James River																			
Deep Water Shoal	D	0	0	0	0	0	0	-	0	0	0	0.05	0	0	-	-	-	0	0.05
Horsehead	D	0	0	0	0	0	0	-	0	0	0	0	0	0	-	-	-	0	0
Point of Shoal	D	0	0	0	0	0	0	-	0	0	0	0	0.1	0	-	-	-	0	0.10
Swash	D	0	0	0	0	0	0	-	0	0	0	0.35	0	0.05	-	-	-	0.05	0.45
Dry Shoal	D	0	0	0	0	0	0	-	0	0	0	0.05	0.15	0.05	-	-	-	0.3	0.55
Rock Wharf	D	0	0	0	0	0	0	-	0	0	0	0.1	0	0	-	-	-	N	0.10
Wreck Shoal	D	0	0	0	0	0	0	-	N	N	0	0.9	0.2	0.05	-	-	-	0.15	1.3
Day's Point	D	0	0	0	N	0	0	-	N	0	0	0.05	0	0	-	-	-	0	0.05
Piankatank River																			
Wilton Creek	D	0	0	-	0	0	0	0	0	0	0	0	0	0.1	0	-	-	0	0.10
Ginney Point	D	0	0	0	0	0	0	0	0	0.1	0	0	0	0.05	0	-	-	0.05	0.20
Palace Bar	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	-	-	N	0.05
Bland Point	D	0	0	0	0	0	0	0	0	0.1	0	0	0	0.05	0	-	-	0	0.15
Heron Rock	D	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	-	-	0	0.20
Cape Toon	D	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	-	-	0	0.05
Stove Point	D	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	-	-	0	0.10
Burton Point	D	0	0	0	0	0	0	0	0	0.05	0	0	0	0.1	0	-	-	N	0.15
Great Wicomico River																			
Glebe Point	D	0	0	0	0	0	0	0	0	-	0	4.75	0	0.1	0	-	-	0.05	4.9
Rogue Point	D	0	0	0	0	0	0	0	0	-	0	6.2	0.2	0.5	0	-	-	0.1	7.0
Hilly Wash	D	0	0	0	0	0	0	0	0	-	0	1.3	0.15	1.45	0	-	-	0	2.9
Harcum Flats	D	0	0	0	0	0	0	0	0	-	0	2.0	0.4	1.25	0	-	-	0.05	3.7
Hudnall	D	0	0	0	0	0	0	0	0	-	0	1.6	0.4	1.1	0	-	-	0	3.1
Shell Bar	D	0	0	0	0	0	0	0	0.05	-	0.1	0.7	0.3	0.65	0.05	-	-	0.05	1.9
Haynie Point	D	0	0	0	0	0	0	0	0	-	0	0.45	0.15	0.95	0.05	-	-	0	1.6
Whaley's East	D	0	0	0	0	0	0	0	0	-	0.05	0.15	0.05	0.5	0.1	-	-	0	0.85
Fleet Point	D	0	0	0	0	0	0	0	0	-	0	0.2	0	0.05	0.1	-	-	N	0.35

Table S2: Spatfall totals for historical sites (1988-2003) and for 1998-2003 at sites where historical data are not available. Values are presented as the cumulative sum of spat $shell^{-1}$ values for each year. "+" and "-" indicate direction of change in 2003 in reference to 2002 and to the five, ten, and fifteen-year means. Blank cells for a site indicate years where data are not available.

STATION	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Mean 98-02	Mean 93-02	Mean 88-02	Ref. 2002	Ref. 5-yr	Ref. 10-yr	Ref. 15-yr
James River																							
Deep Water Shoal	4.3	2.0	2.6	10.6	0.7	15.7	0.6	1.7	0.5	1.3	1.2	5.7	0.7	2.0	33.8	0.1	8.7	6.3	5.6	-	-	-	-
Horsehead	3.5	1.5	0.9	24.7	3.6	43.7	3.2	0.3	3.6	2.4	1.1	3.8	2.3	4.0	24.4	0.0	7.1	8.9	8.2	-	-	-	-
Point of Shoal	41.7	3.7	14.3	21.4	5.4	73.7	15.0	4.8	2.3	2.3	1.5	3.5	0.7	4.0	31.3	0.1	8.2	13.9	15.0	-	-	-	-
Swash	7.6	3.8	3.3	68.7		46.2	4.8	1.8	2.2	1.7	1.6	6.8	2.6	3.5	26.0	0.5	8.1	9.7	12.9	-	-	-	-
Dry Shoal	13.2	10.0	30.9	217.1	14.2	119.0	25.8	2.8	11.0	1.1	1.1	6.1	3.7	2.1	16.5	0.6	5.9	18.9	31.6	-	-	-	-
Rock Wharf	9.9	2.1	1.8		11.4	34.3	10.7	0.2	2.4	5.6	2.1	8.0	1.0	8.5	22.7	0.1	8.5	9.6	8.6	-	-	-	-
Wreck Shoal	6.4	10.2	4.0	35.3	3.3	15.5	2.2	2.6	10.0	0.7	0.7	3.1	0.9	3.2	8.3	1.3	3.2	4.7	7.1	-	-	-	-
Day's Point	17.3	26.1	22.4	145.6	14.2	131.5	42.2	3.0	4.6	5.6	0.4	7.3	4.3	1.6	10.5	0.1	4.8	21.1	29.1	-	-	-	-
Piankatank River																							
Wilton Creek											1.9	5.9	3.6	0.2	6.5	0.1	3.6			-	-		
Ginney Point	3.3	29.9	62.6	25.4	11.4	1.7	0.0	0.5	1.3	0.0	2.2	6.4	6.8	1.2	5.9	0.2	4.5	2.6	10.6	-	-	-	-
Palace Bar	3.6	42.4	119.2	38.9	24.9	5.0	0.8	1.0	1.6	0.0	5.5	10.1	3.9	0.2	3.1	0.1	4.6	3.1	17.3	-	-	-	-
Bland Point											2.3	44.1	2.7	1.3	6.7	0.2	11.4			-	-		
Heron Rock											10.1	9.3	3.2	0.6	5.1	0.2	5.7			-	-		
Cape Toon											4.5	12.3	1.2	1.8	9.1	0.1	5.8			-	-		
Stove Point											1.0	7.1	1.8	1.6	31.0	0.1	8.5			-	-		
Burton Point	2.0	31.6	87.4	16.4	11.7	6.5	0.1	1.0	1.0	0.7	1.3	14.9	2.7	0.8	4.9	0.2	4.9	3.4	12.2	-	-	-	-
Great Wicomico River																							
Glebe Point	23.9	8.2	19.5	1.9	0.5	0.2	0.0	1.5	0.6	21.2	0.6	2.4	4.2	1.1	283.3	4.9	58.3	31.5	24.6	-	-	-	-
Rogue Point											0.9	2.0	2.6	0.7	16.6	7.0	4.6			-	+		
Hilly Wash											0.6	1.6	3.2	0.8	24.1	2.9	6.1			-	-		
Harcum Flats											0.1	1.3	0.8	1.1	33.7	3.7	7.4			-	-		
Hudnall	51.3	26.4	94.8	4.5	0.5	0.8	0.0	0.1	0.2	39.1	0.5	0.9	1.0	1.4	12.7	3.1	3.3	5.7	15.6	-	-	-	-
Shell Bar											0	2.9	0.8	0.8	17.8	1.9	4.5			-	-		
Haynie Point	38.5	17.0	68.2	12.4	0.6	1.4	0.0	1.0	3.7	4.4	0.7	1.1	1.1	0.9	15.4	1.6	3.8	3.0	11.1	-	-	-	-
Whaley's East	14.6	8.4	39.1	7.9	0.1	0.2	0.0	0.3	2.1	1.0	0.4	1.8	0.2	0.7	2.4	0.9	1.1	0.9	5.3	-	-	NC	-
Fleet Point	8.7	7.9	17.4	5.8	2.9	2.0	0.0	0.3	2.6	3.4	0.3	0.5	0.6	1.0	3.9	0.4	1.3	1.5	3.8	-	-	-	-

Figure S1: Map showing the location of the 2003 shellstring sites. An N following the site name indicates a new site as specified in the text; all other sites are historical.

James River: 1) Deep Water Shoal, 2) Horsehead, 3) Point of Shoal, 4) Swash, 5) Dry Shoal, 6) Rock Wharf, 7) Wreck Shoal, 8) Day's Point.

Piankatank River: 9) Wilton Creek (N), 10) Ginney Point, 11) Palace Bar, 12) Bland Point (N), 13) Heron Rock (N), 14) Cape Toon (N), 15) Stove Point (N), 16) Burton Point.

Great Wicomico River: 17) Glebe Point, 18) Rogue Point, 19) Hilly Wash (N), 20) Harcum Flats (N), 21) Hudnall, 22) Shell Bar (N), 23) Haynie Point, 24) Whaley's East, 25) Fleet Point.

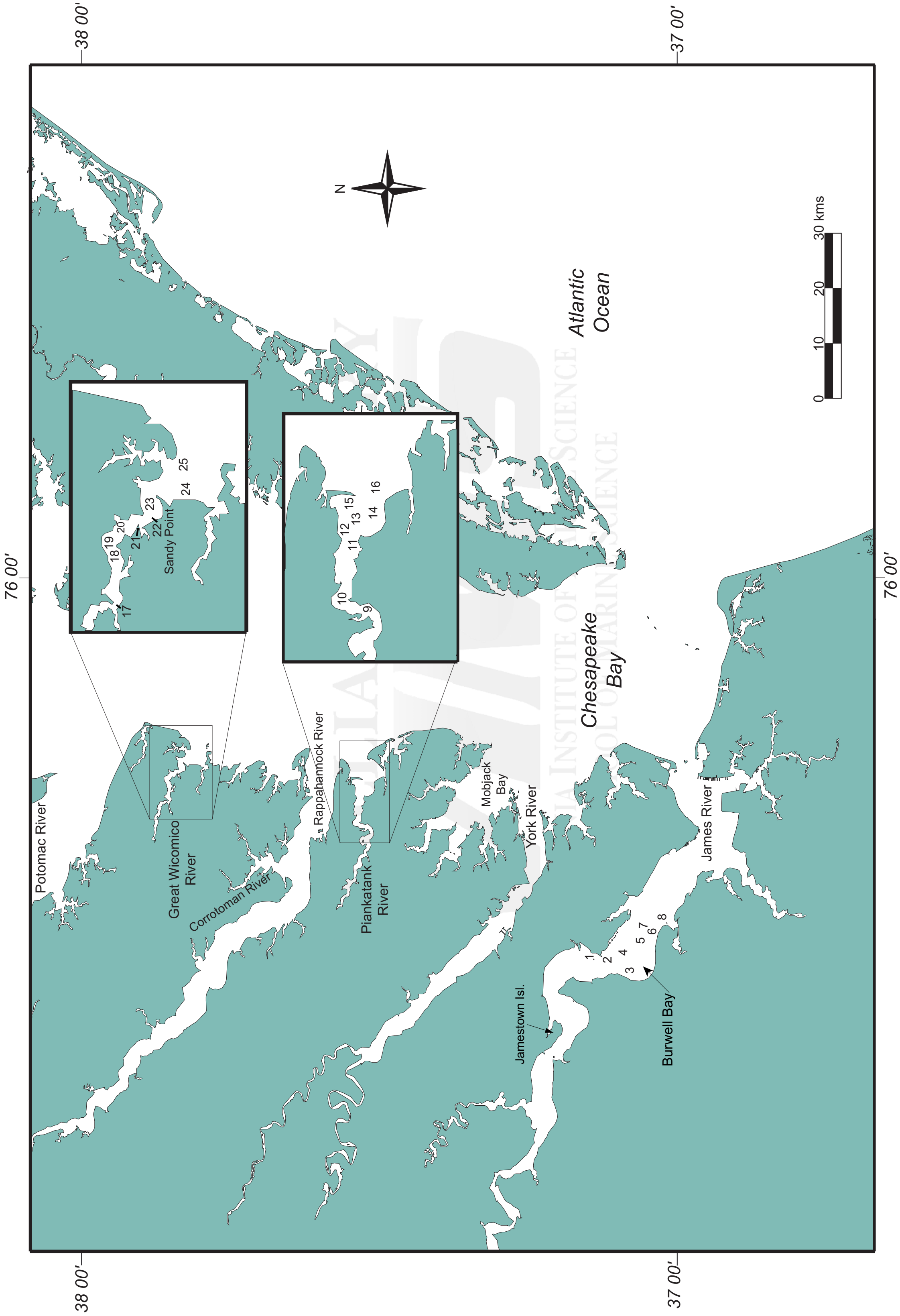
38 00'
37 00'
76 00'
N
Atlantic
Ocean
Chesapeake
Bay
0
10
20
30 kms
Potomac River
Great Wicomico
River
Corrotoman River
Rappahannock River
Piankatank
River
Mobjack
Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
1
2
3
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Figure S2: Map showing the location of the artificial oyster reefs in the Virginia portion of the Chesapeake Bay.

Lynnhaven River: 1) Eastern Branch Reef, 2) Humes Marsh Reef, 3) Long Creek Reef, 4) Broad Bay Reef.

Lafayette River: 5) Hampton Boulevard Bridge Reef, 6) Tanner's Point Reef.

Elizabeth River: 7) Western Branch Reef, 8) Craney Island Reef, 9) Ford Plant Reef, 10) Deep Creek Reef, 11) Gilmerton Reef, 12) Port Authority Reef.

Back River: 13) Langley Reef.

York River: 14) Felgate's Creek Reef, 15) Amoco Reef.

Mobjack Bay: 16) Ware River Reef, 17) North River Reef, 18) East River Reef.

Piankatank River: 19) Palace Bar Reef, 20) Bland Point Reef, 21) Iron Point Reef, 22) Burton Point Reef.

Rappahannock River: 23) Upper Waterview Reef, 24) Weeks Reef, 25) Lagrange Creek Reef, 26) Towles Point Reef, 27) Temple Bay Reef, 28) Drumming Ground Reef, 29) Ferry Bar Reef, 30) Parrot's Rock Reef, 31) Mill Creek Reef, 32) Mosquito Point Reef, 33) Sturgeon Bar Reef, 34) Broad Creek Reef, 35) Butler's Hole Reef.

Great Wicomico River: 36) Shell Bar Reef, 37) Cranes Creek Reef.

Potomac River: 38) Indian Bar Reef, 39) Kinsale Point Reef, 40) Crow Bar Reef, 41) Coan River Reef.

Eastern Shore: 42) Pungoteague Creek Reef, 43) Fishermen Island Reefs.

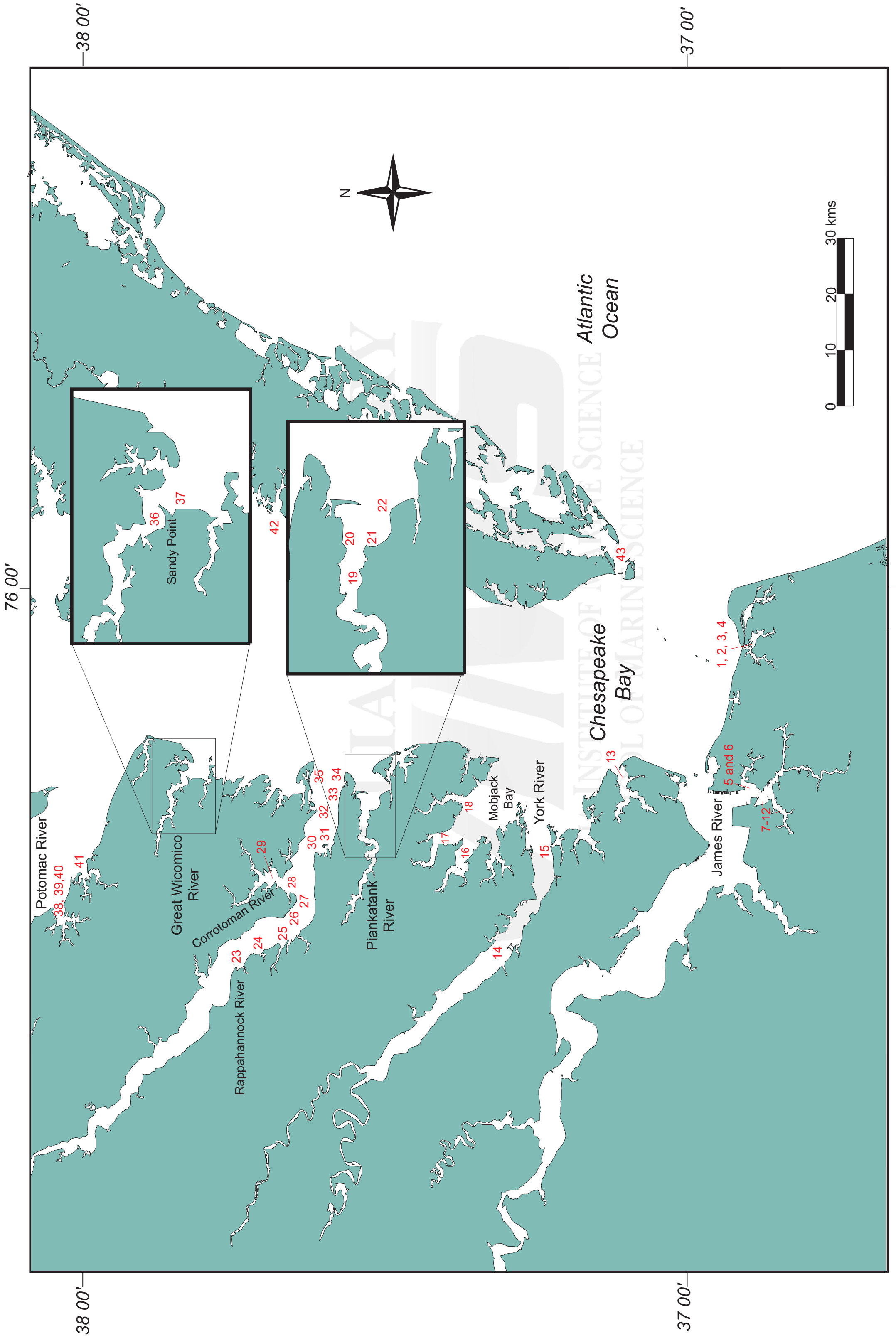

38 00'
37 00'
76 00'
N
Atlantic
Ocean
Chesapeake
Bay
0
10
20
30 kms
Potomac River
38, 39,40
41
Great Wicomico
River
Sandy Point
36
37
42
Corrotoman River
Rappahannock River
23
24
25
26
27
28
29
30
31
32
33
34
35
Piankatank
River
19
20
21
22
Mobjack
Bay
York River
14
15
16
17
18
13
43
1, 2, 3, 4
James River
5 and 6
7-12

Figure S3: Diagram of shellstring setup on buoys.

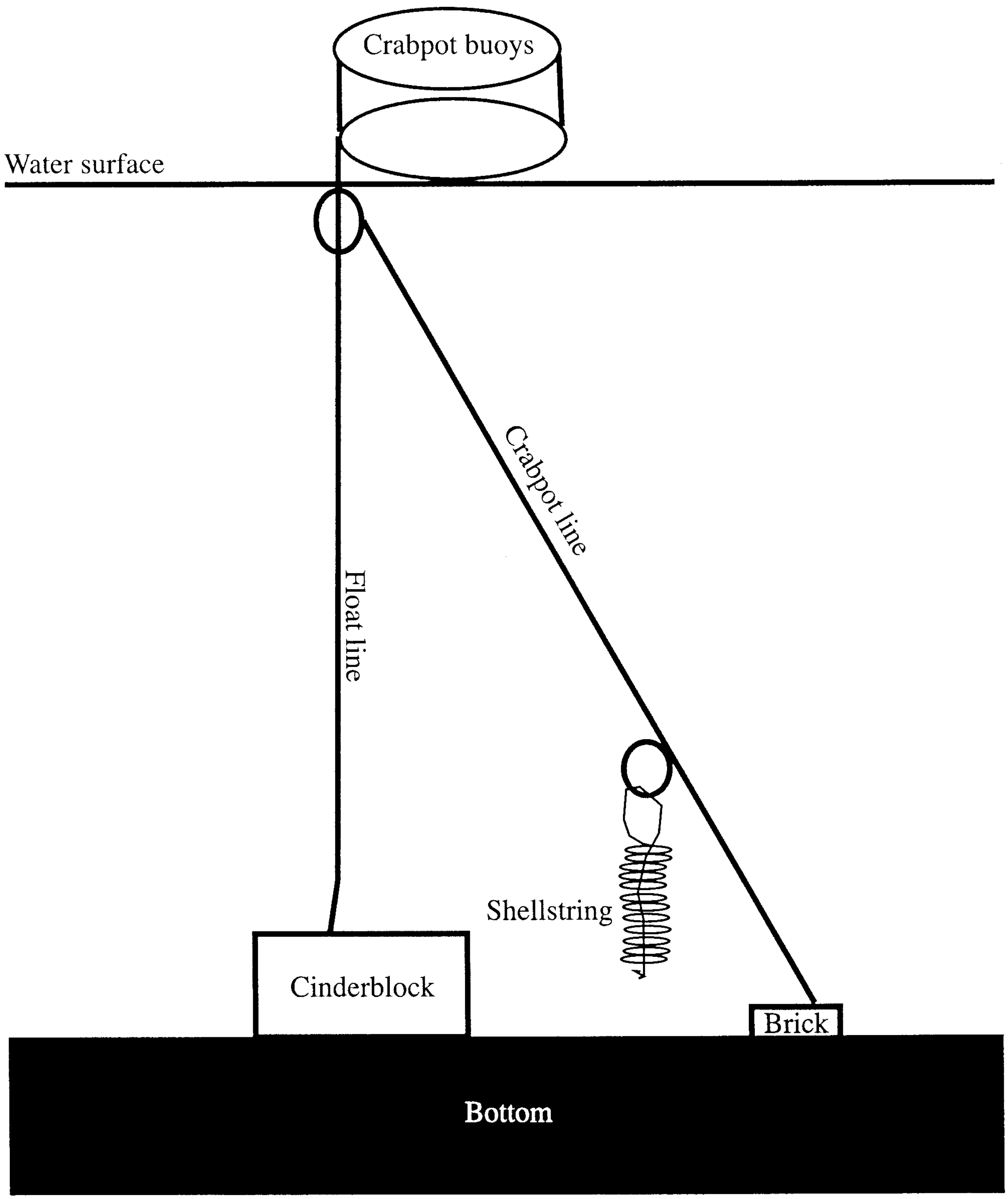


FIGURE S4: JAMES RIVER (2003) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

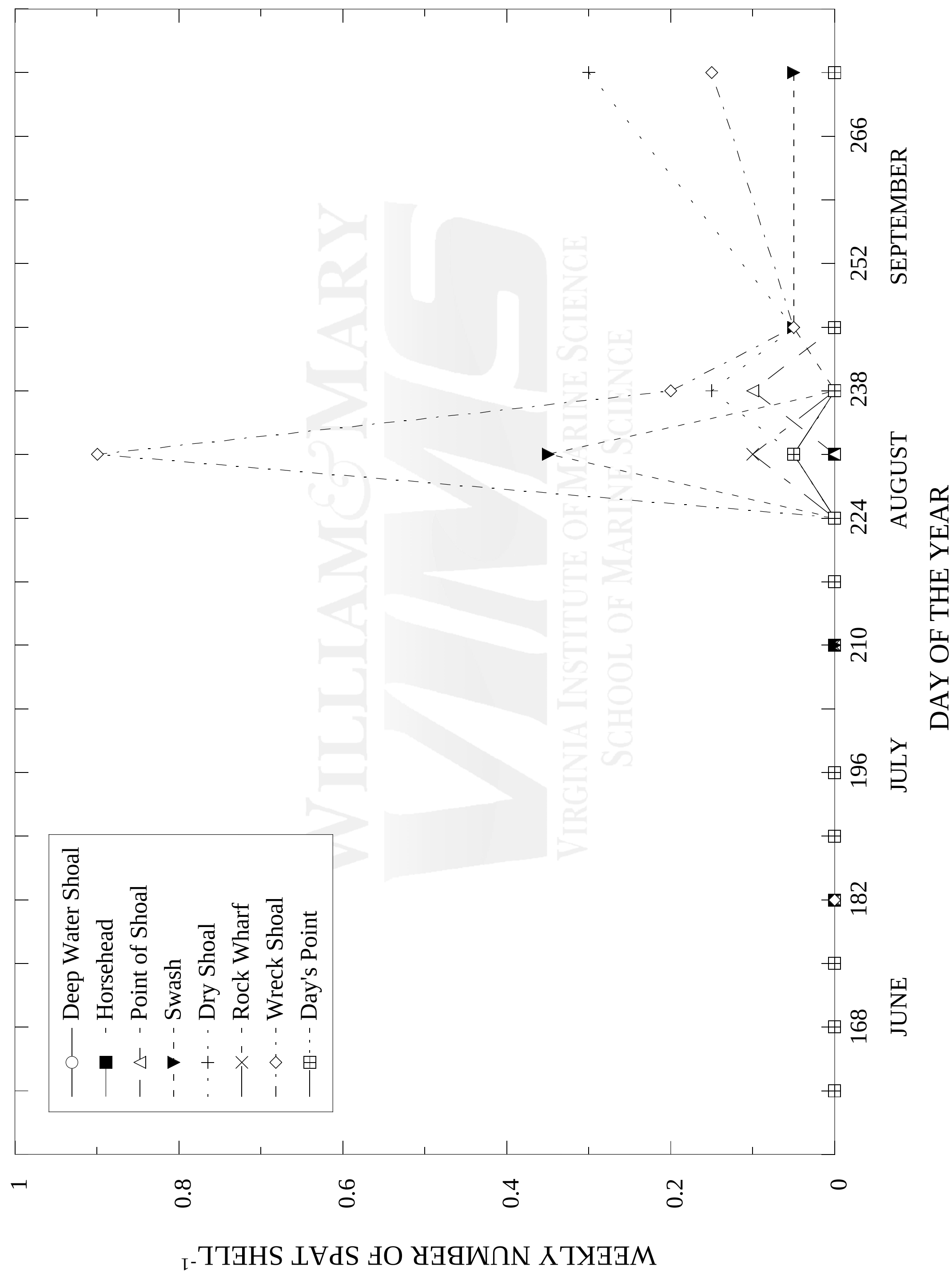


FIGURE S5: SPATFALL TRENDS OVER THE PAST 15 YEARS AT ALL EIGHT SITES IN THE JAMES RIVER (upriver sites in top panel; downriver sites in bottom panel) (expressed as cumulative weekly spatfall)

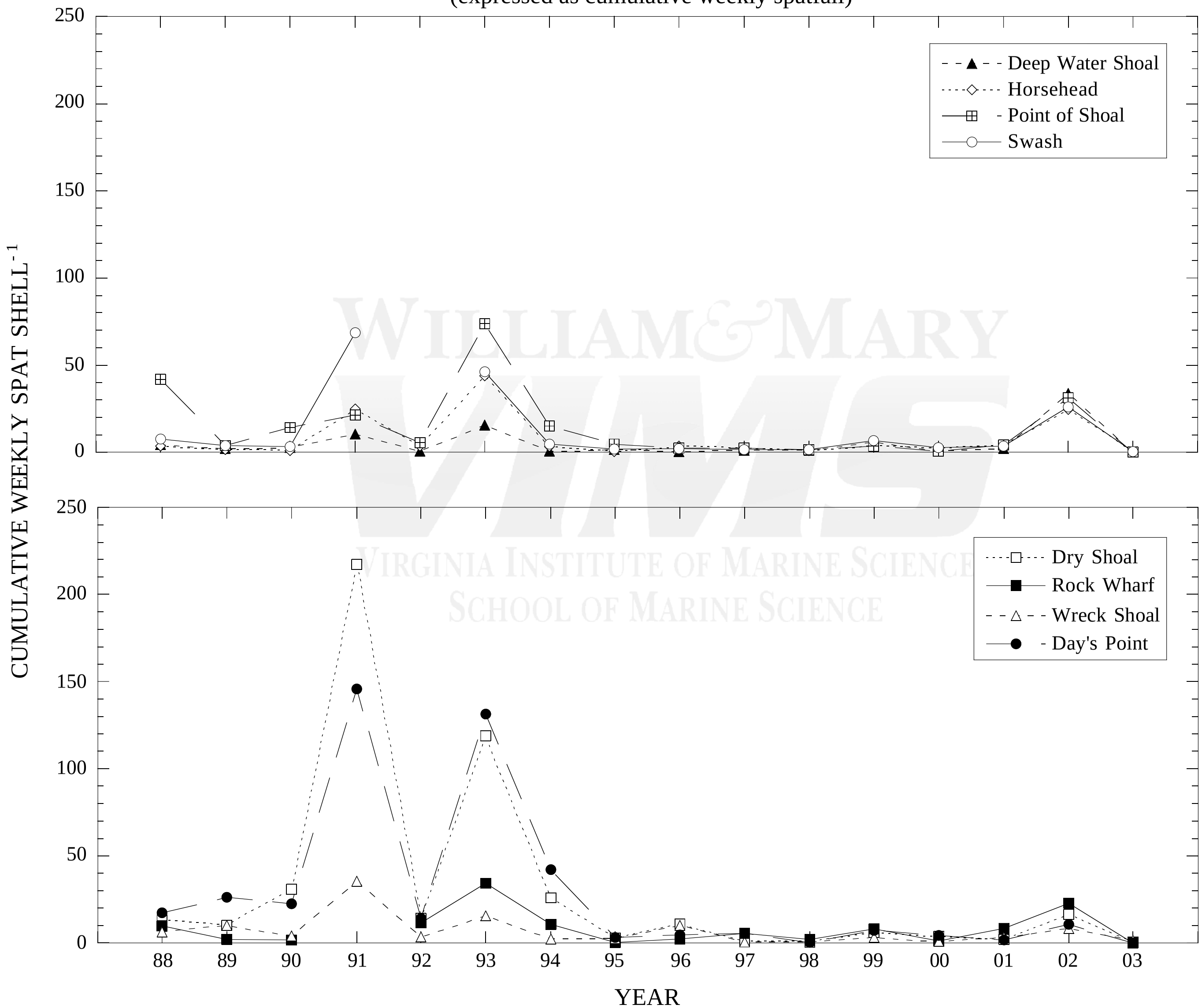


FIGURE S6: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5 AND 10-YEAR MEANS COMPARED WITH 2003
(error bars represent standard error of the mean; shaded areas represent settlement in 2003)

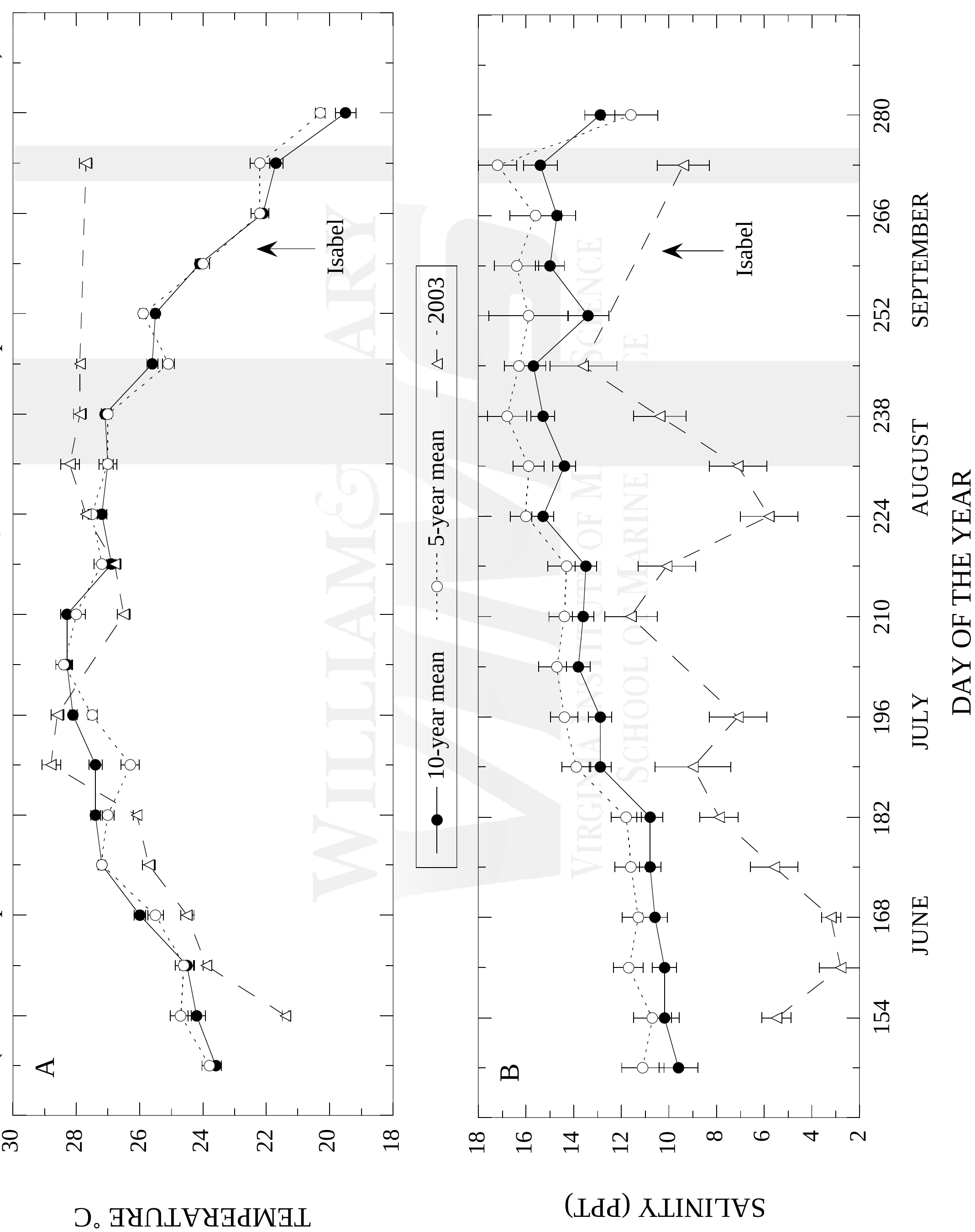


FIGURE S7: PIANKATANK RIVER (2003) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

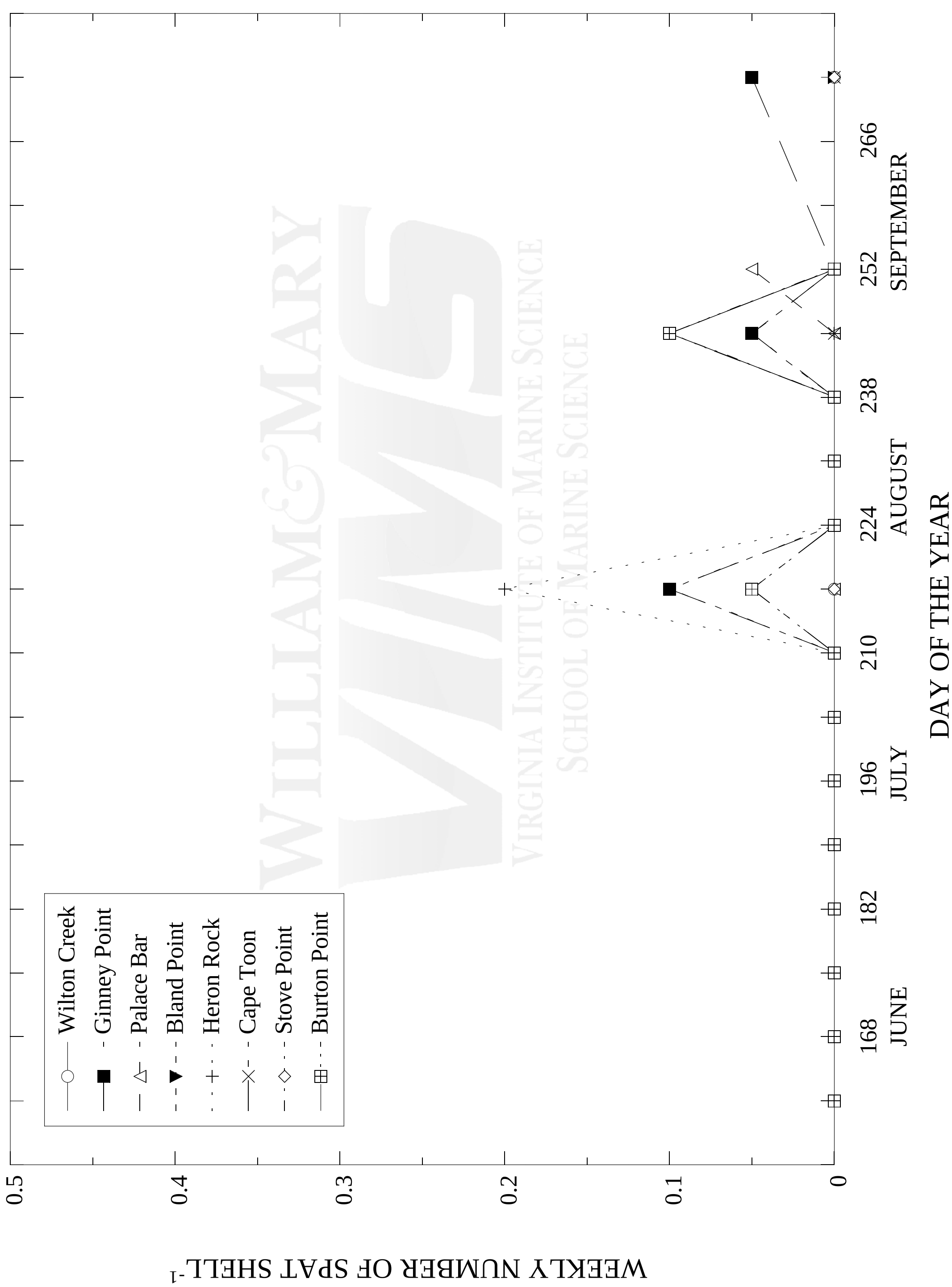


FIGURE S8: SPATFALL TRENDS OVER THE PAST 15 YEARS AT THE THREE HISTORICAL SITES IN THE PIANKATANK RIVER
(expressed as cumulative weekly spatfall)

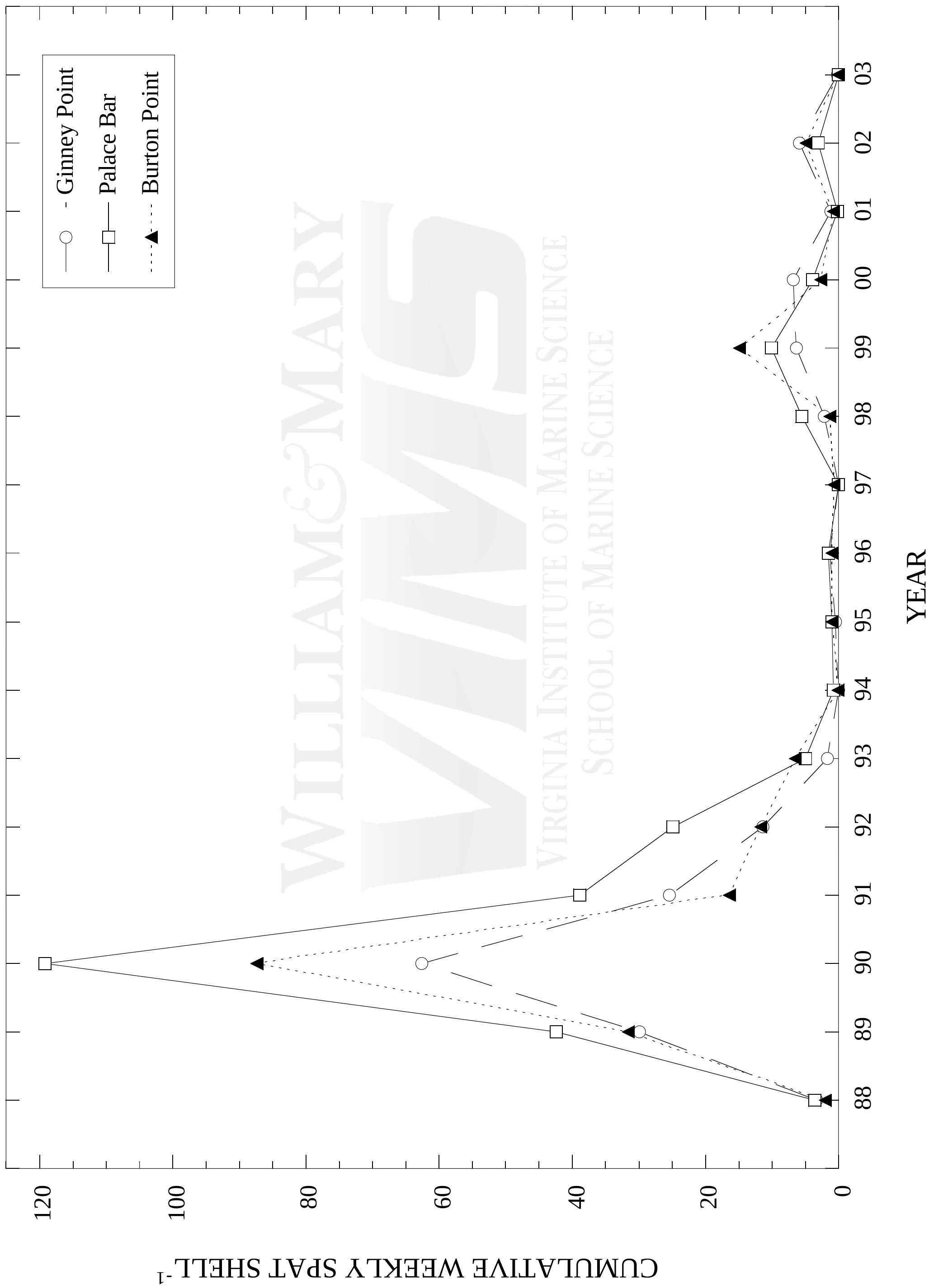


FIGURE S9: SPATFALL TRENDS OVER THE PAST 5 YEARS AT THE NINE "NEW SITES" IN THE PIANKATANK (top panel) AND GREAT WICOMICO (bottom panel) RIVERS (expressed as cumulative weekly spatfall)

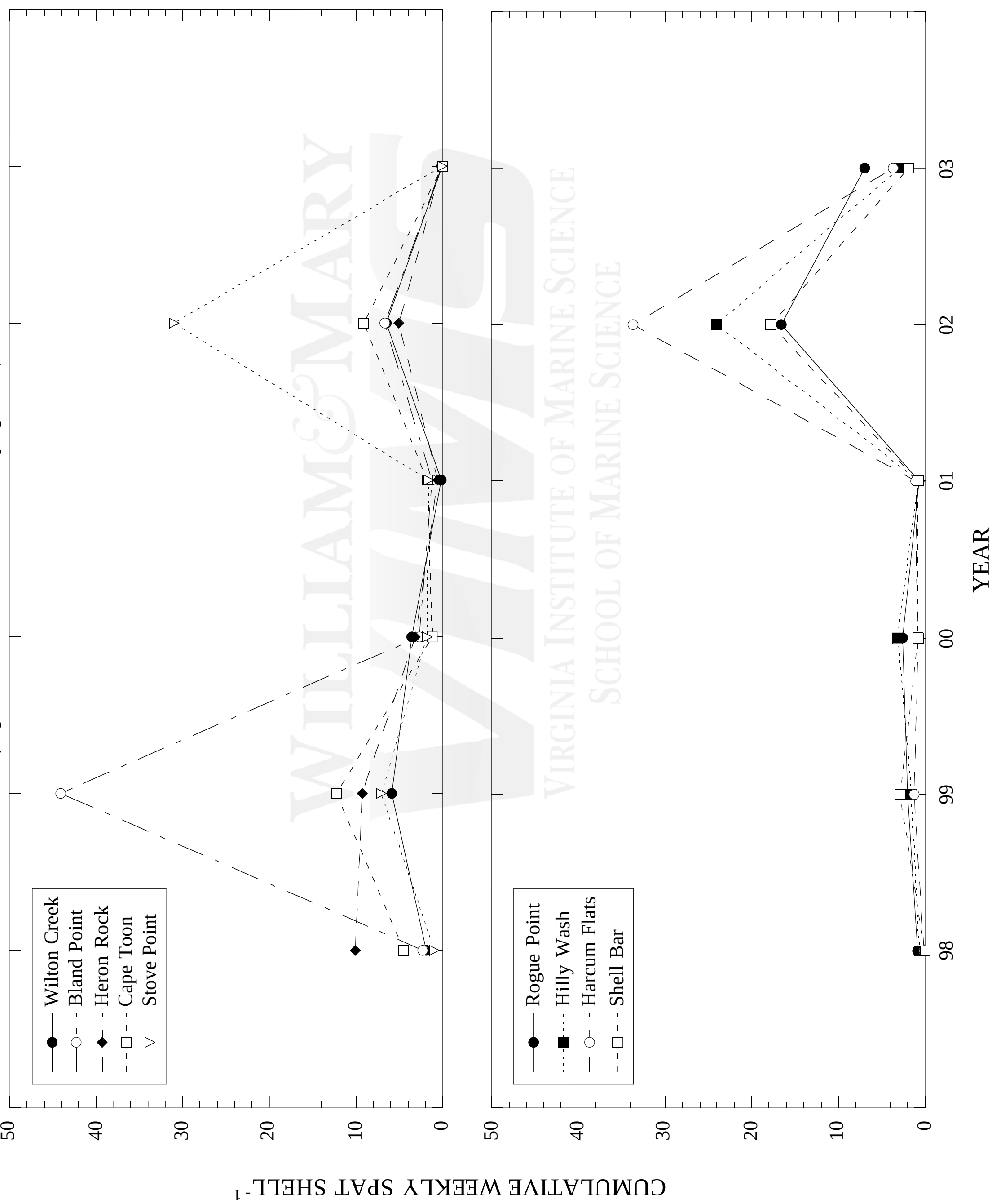


FIGURE S10: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5 AND 10-YR MEANS COMPARED WITH 2003
(error bars represent standard error of the mean; shaded areas represent settlement during 2003)

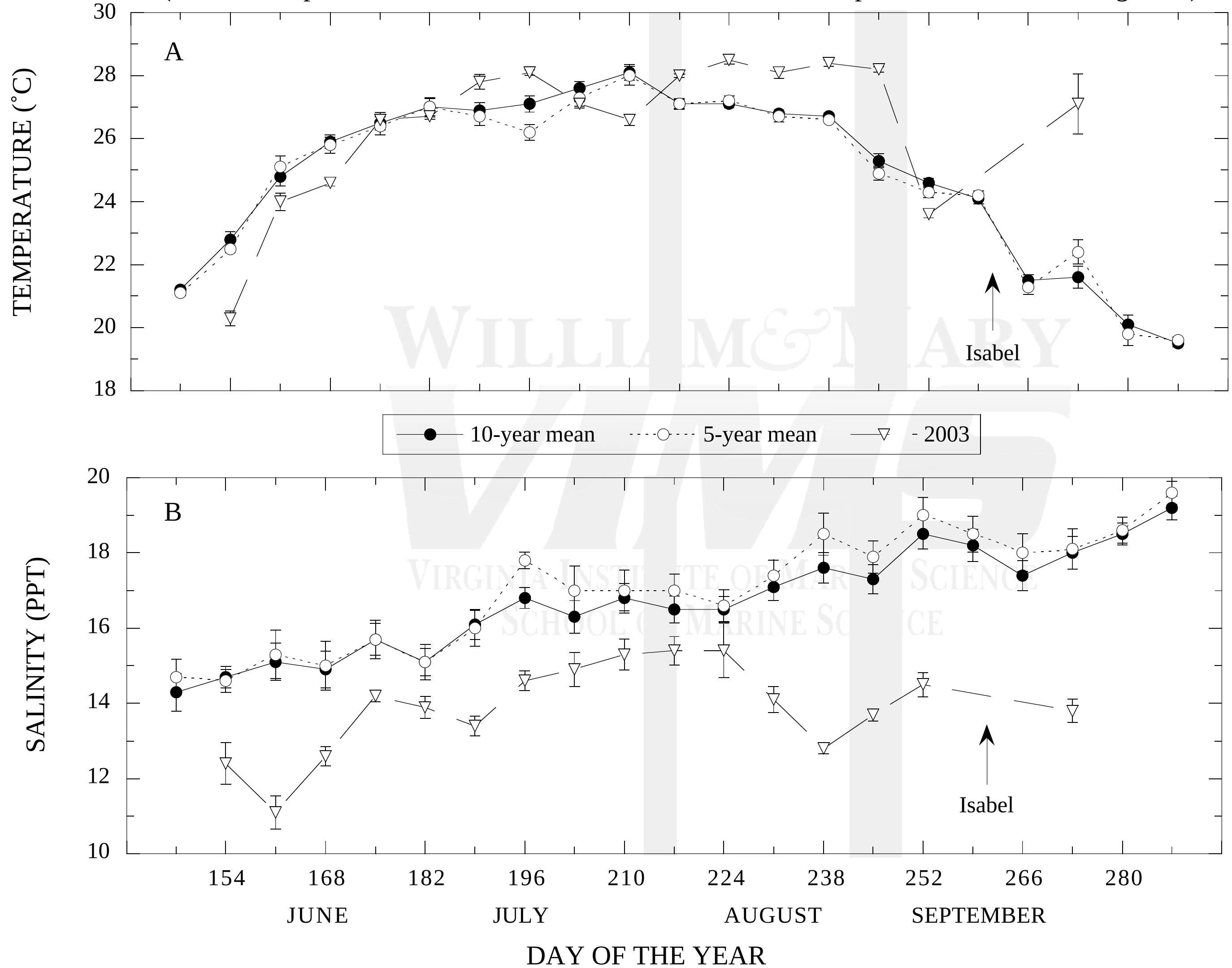


FIGURE S11: GREAT WICOMICO RIVER (2003) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

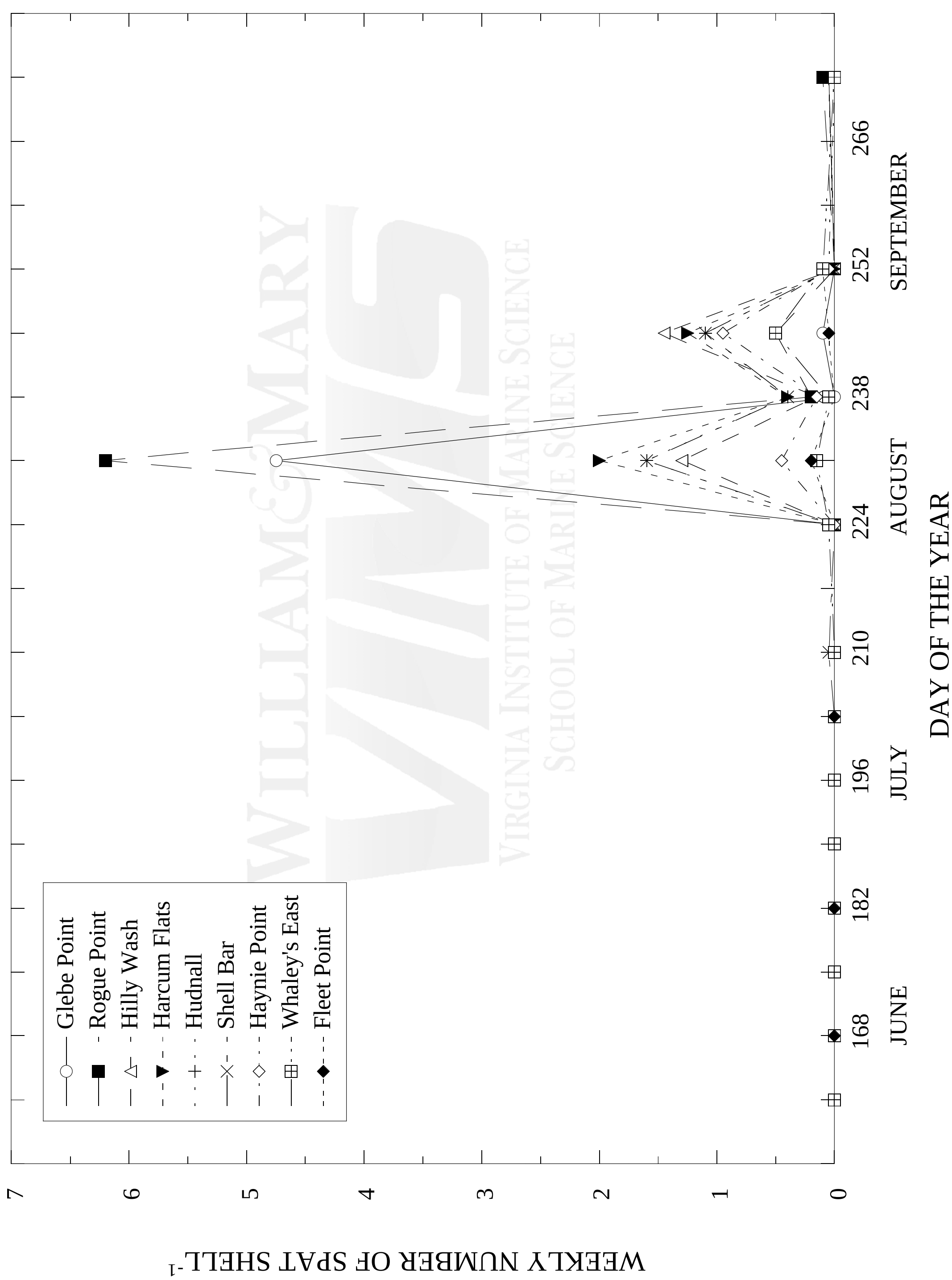


FIGURE S12: SPATFALL TRENDS OVER THE PAST 15 YEARS AT THE FIVE HISTORICAL SITES IN THE GREAT WICOMICO RIVER
(expressed as cumulative weekly spatfall)

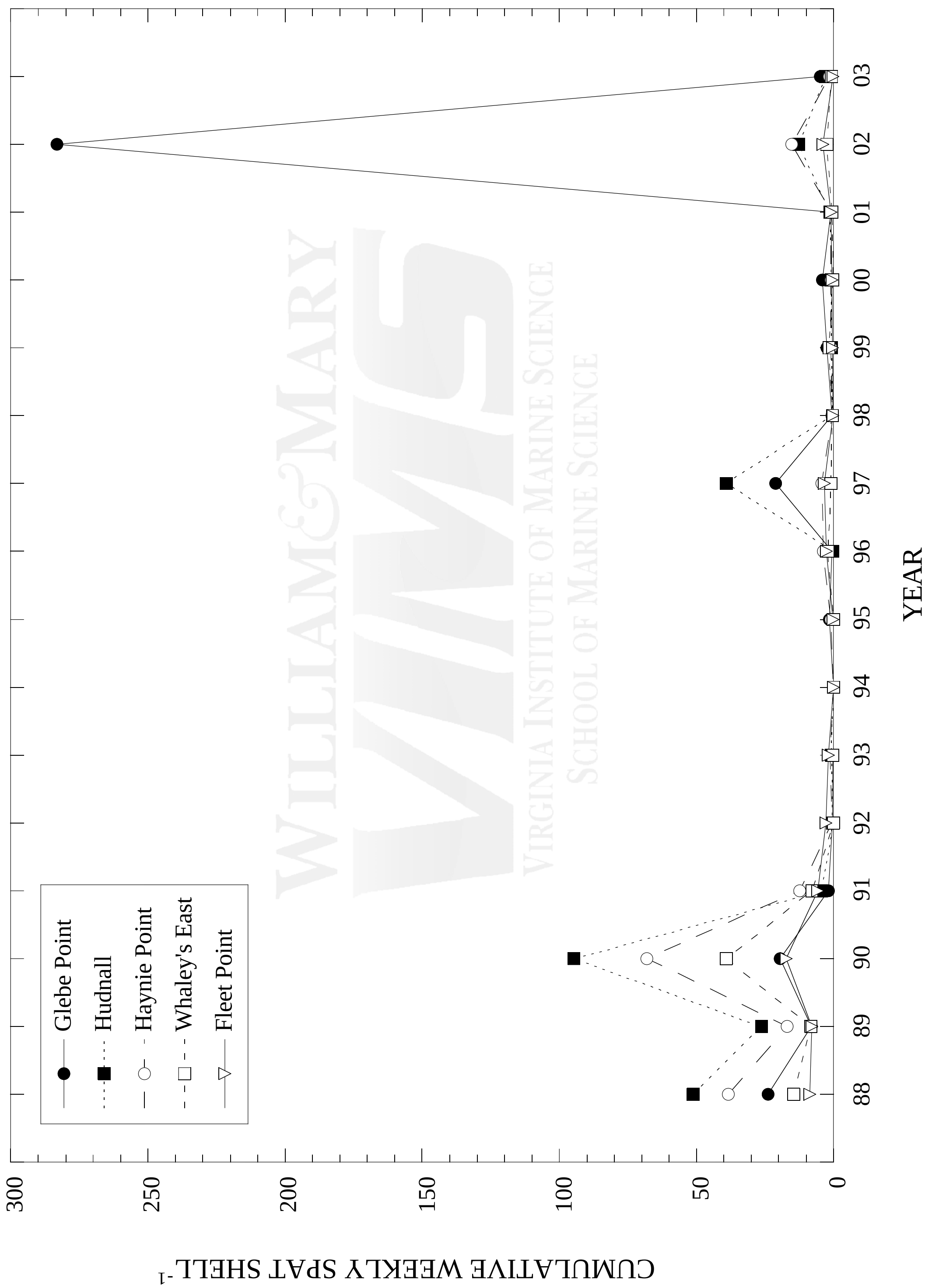
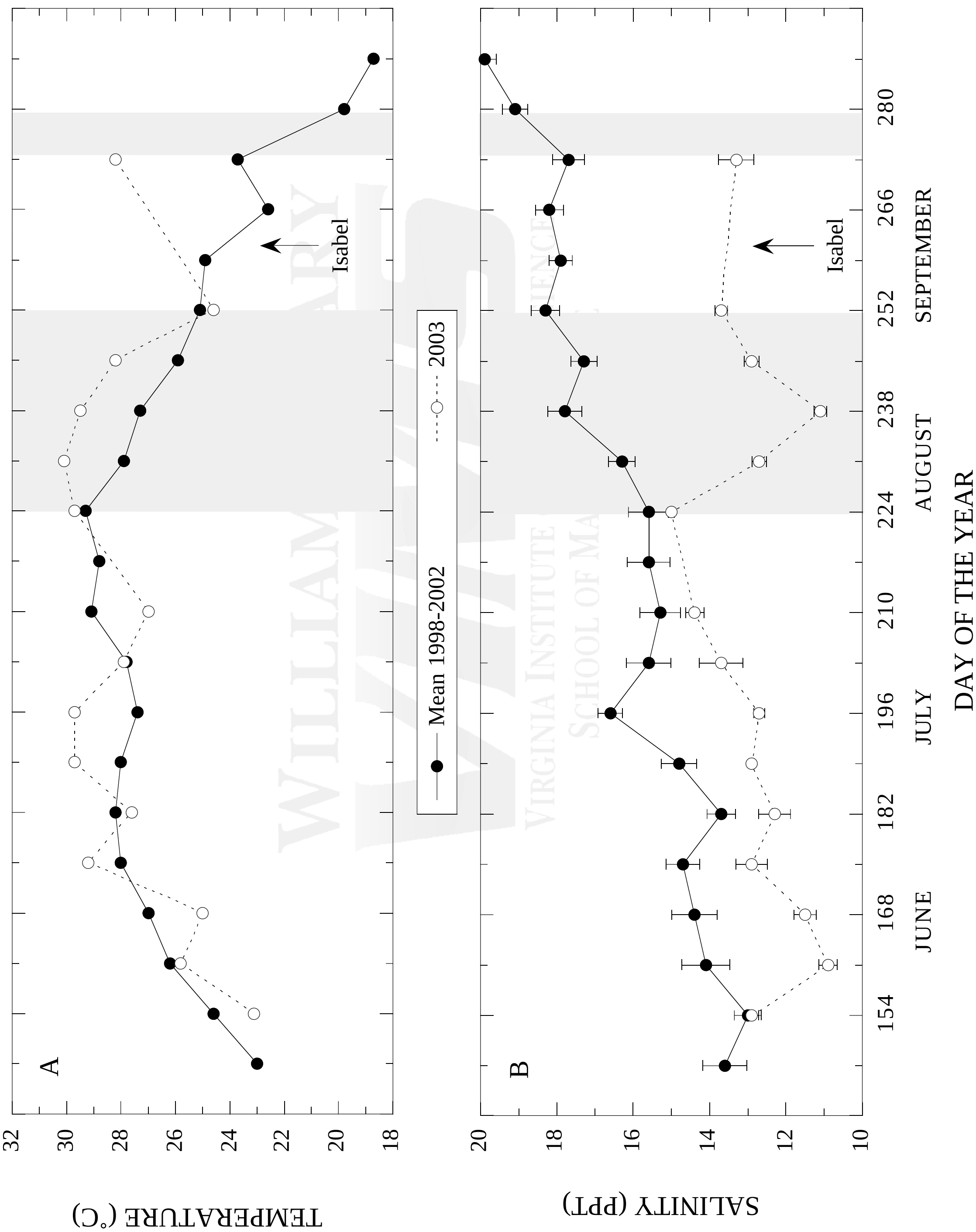


FIGURE S13: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5-YEAR MEAN COMPARED WITH 2003
(error bars represent standard error of the mean; shaded areas represent settlement during 2003)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2003

INTRODUCTION

The Eastern oyster, *Crassostrea virginica* (Gmelin 1791), has been harvested from Virginia waters as long as humans have inhabited the area. Accelerating depletion of natural stocks during the late 1880s led to the establishment of oyster harvesting regulations by public fisheries agencies. A survey of bottom areas in which oysters grew naturally was completed in 1896 under the direction of Lt. J. B. Baylor, U.S. Coast and Geodetic Survey. These areas (over 243,000 acres) were set aside by legislative action for public use and have come to be known as the Baylor Survey Grounds or Public Oyster Grounds of Virginia; they are presently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) conducts a dredge survey of selected public oyster bars in Virginia tributaries of the western Chesapeake Bay to assess the status of the existing oyster resource. These surveys provide information about spatfall and recruitment, mortality, and changes in abundance of seed and market-size oysters from one year to the next. This section summarizes data collected during bar surveys conducted during October 2003.

Spatial variability in distribution of oysters over the bottom can result in wide differences among dredge samples. Large differences among samples collected on the same day from one bar are an indication that distribution of oysters over the bottom is highly variable. An extreme example of that variability can be found in Southworth et al. (1999) by the width of the confidence interval around the average count of spat at Horsehead (James River, VA) during 1998. Therefore, in the context of the present sampling protocol, differences in average counts found at one bar between seasons in the same year or between counts for the same season in different years may be the result of sampling variation rather than actual short-term changes in abundance. If the observed changes persist for several years or can be attributed to well-documented physiological or environmental factors, then they may be considered a reflection of actual changes in abundance with time.

METHODS

Locations of the oyster bars sampled by VIMS during October 2003 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1.

Four samples of bottom material were collected at a single station on each bar using an oyster scrape dredge. In all surveys in the York River and Mobjack Bay (through 2003) and in all surveys in the James, Piankatank, Rappahannock, and Great Wicomico Rivers preceding 1995, sampling was effected using a 2-ft wide dredge with 4-in teeth towed from a 21-ft boat; volume collected in the dredge bag was 1.5 bushels. Beginning in 1995, samples were collected using a 4-ft dredge with 4-in teeth towed from the 43-ft long VMRC vessel J. B. Baylor; volume collected in the bag of that dredge is 3 bushels. Note that the bushel measure used is a Virginia bushel which is equivalent to 3003.9 cubic inches. A Virginia bushel differs in volume from both a U.S. bushel (2150.4 cubic inches) and a Maryland bushel (2800.7 cubic inches). In all surveys a half-bushel (25 quarts) subsample was taken from each tow for examination. Data presented give the average of the four samples collected at each station for live oyster and box counts after conversion to a full bushel.

From each half bushel sample, the number of market oysters (76 mm = 3-in. in length or larger), small oysters (< 76 mm, excluding spat), spat (recently settled, 2003 recruits), new boxes (inside of shells perfectly clean; presumed dead for approximately < 1 week), old boxes, and spat boxes were counted. The presumed time period since death of an oyster associated with the two categories of boxes is a qualitative description based on visual observations. Temperature (in °C) and salinity (in ppt, parts per thousand) were recorded at each of the dredge stations at the time of sampling using an alcohol thermometer and a hand-held refractometer.

During spring and early summer 2003, the following changes that may have had some effect on settlement and oyster abundance were made (Figure D1 and D2 for locations). As part of VMRC repletion efforts, clean shells (cultch) were planted on Drumming Ground and Broad Creek in the Rappahannock River, and on Ginney Point and Palace Bar in the Piankatank River. There were no broodstock placed on the artificial reefs during 2003 in any of the river systems. The only seed moved between the 2002 and 2003 spawning season was from the Great Wicomico River to several newly built reefs in Tangier Sound on the Eastern Shore of the Chesapeake Bay.

RESULTS

Thirty oyster bars were sampled between October 15 and October 24, in six of the major Virginia tributaries on the western shore of the Chesapeake Bay. Bar locations are shown in Figure D1 and Table D1. It should be noted that Bell Rock in the York River is a private bar and is included in this report for historical reasons. Results of this survey are summarized in Table D2 and, unless otherwise indicated, the numbers presented below refer to that table.

James River

Ten bars were sampled in the James River, between Nansemond Ridge at the lower end of the river and Deep Water Shoal near the uppermost limit of oyster distribution in the system. The highest average number of live oysters was found at Horsehead (988 bushel^{-1}). Numbers at Swash, Long Shoal, and Mulberry Point were moderately low with 510, 538, and 596 oysters bushel^{-1}, respectively. Of the other six stations sampled the total number of live oysters was low ranging from a low of 91 (Nansemond Ridge) to a high of 377 (Point of Shoal) oysters bushel^{-1}.

The overall number of market oysters in the James River continues to be low when compared with historical numbers. In contrast to previous years, the three most upriver stations had a very low number of market oysters (Figure D4A). For the first time in fifteen years there were no market oysters found at Deep Water Shoal. Only two of the upriver sites (Point of Shoal and Long Shoal) had a moderate number of market oysters, the other four sites had very low numbers. At the six most upriver sites, there was either no change or a notable decrease in the number of market oysters, whereas there was an increase in market oysters at the four most downriver sites (Figures D1 and D3).

When compared with 2002, there was a relatively large increase in the number of small oysters bushel^{-1} at all of the sites sampled except at Nansemond Ridge where there was no change and Deep Water Shoal where there was a decrease (Figure D3, D4A and D4B). Numbers of small oysters bushel^{-1} ranged from a low of 65 at Nansemond Ridge to a high of 978 at Horsehead.

The overall number of spat was very low throughout the entire river system ranging from a low of 0 (Deep Water Shoal, Mulberry Point, and Swash) to a high of 33 bushel^{-1} (Wreck Shoal). Given the large amount of spatfall that was observed during 2002, this represented a large decrease for 2003 when compared with 2002 at all ten stations sampled (Figure D3, D4A, and D4B). Spatfall at most stations was among the lowest observed over the past fifteen years. In the past, there has been a relationship between location in the river and the composition of live oysters in terms size distribution. As one moves from the most upriver station (Deep Water Shoal) to the most downriver station (Nansemond Ridge: Figure D1), the percentage of small oysters tends to decrease while the percentage of spat tends to increase. This pattern was also observed to a certain extent during 2003. However, given the combination of a lack of spatfall throughout the river during 2003 with the large number of spat from the previous year surviving and growing to become small oysters, nine out of the ten sites sampled had a make-up of greater than 80% small oysters.

The average number of boxes bushel^{-1} ranged from a low of 12 (Nansemond Ridge) to a high of 339 (Mulberry Point). In contrast to previous years when Long Shoal had the greatest number of boxes, the greatest number of boxes during 2003 occurred at the more upriver stations, with numbers decreasing as one moves toward the mouth of the river system. Boxes accounted for less than 25% of the total oysters found (live and dead) at all of the stations except Deep Water Shoal, Mulberry Point, and Point of Shoal which accounted for 68, 36, and 27% of the total respectively. Of these boxes, an average of 36% were new boxes, a much higher percentage than has been observed in the past.

Water temperature during the sampling period remained fairly constant ranging from 16 to 17°C (Table D2). Salinity was more variable depending on location in the river, increasing in a downriver direction, from 7 ppt at Deep Water Shoal to 15 ppt at Thomas Rock and 13 ppt at Nansemond Ridge.

York River

The average total number of live oysters bushel^{-1} in the York River was 65 at Aberdeen Rock and 190 at Bell Rock. The live oysters found at both bars were predominately small accounting for 94 (Aberdeen Rock) and 98% (Bell Rock) of the total. There was a notable decrease in market oysters at Bell Rock and a decrease in spat at both sites (Figure D5 and D6). There was also a notable increase in the number of small oysters at both sites. The total number of boxes (new and old) bushel^{-1} was moderate at both sites, 27 bushel^{-1} at Bell Rock and 17 bushel^{-1} at Aberdeen Rock, accounting for 13 and 20% of the total oysters (live and dead) respectively. Water temperature on the day of sampling was 18°C at Bell Rock and 18.5°C at Aberdeen Rock. There was a 4 ppt difference in salinity observed: 13 ppt at Bell Rock and 17 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters bushel^{-1} in Mobjack Bay was very low. In all samples collected at Pultz Bar, there were a total of 4 markets, 1 spat, and 2 boxes counted. At Tow Stake there were 160 live oysters bushel^{-1} with the majority of these in the small size range. The only notable change from 2002 was a relatively large increase in the number of spat at Tow Stake (Figure D5 and D6). 2003 marked the fifth year in a row with very low numbers of oysters at Pultz Bar. While the numbers of both small and market oysters at Tow Stake had been increasing during the late 1990's, 2003 marked the second year in a row where these numbers have decreased. The total number of boxes was moderate at Tow Stake accounting for 14% of the total oysters (live and dead) observed. Of these boxes 59% were spat boxes and 5 out of the 16 spat boxes observed appeared to have been caused by oyster drills (presence of drill hole). Water temperature was 20°C and salinity was 17 ppt (Table D2) at both stations on the day of sampling.

Piankatank River

The average total number of live oysters bushel^{-1} in the Piankatank River was low at all three stations ranging from 64 at Burton Point to 375 at Palace Bar. The number of market size oysters at all three stations continues to be low, but has been on a steady increase since 1996 including an increase at Palace Bar between 2002 and 2003, with little or no change in numbers at the other two stations (Figure D7 and D8). The majority of live oysters observed were small, accounting for greater than 85% of the total live oysters at all three stations. This constituted a substantial increase in the number of small oysters at Palace Bar, a small increase at Burton Point and no change at Ginney Point when compared with 2002 (Figure D7). Spat on the other hand exhibited a large decrease at all three stations. Discounting 2000 and 2001 (both low settlement years), spatfall in the Piankatank had been steadily increasing since 1997 (Figure D8). Settlement during 2003 however, was the lowest observed over the past fifteen years throughout the river system. There were a moderate number of boxes bushel^{-1} observed at all three sites ranging from 29 (Burton Point) to 43 (Palace Bar). The observed boxes were approximately 75% old and 25% new. There were no spat boxes observed in any of the samples. Water temperature on the day of sampling ranged between 18 (Burton Point) and 20°C (Ginney Point). Salinity at the three stations was between 11 and 12 ppt (Table D2).

Rappahannock River

The average total number of live oysters bushel^{-1} in the Rappahannock River was low at all ten stations sampled ranging from 20 (Bowler's Rock) to 199 (Drumming Ground). There appears to be no relationship between the total number of live oysters and location in the river (i.e., upriver vs. downriver: Figure D1), temperature, or salinity (Table D2) as seen in the James River. However, the four stations with the highest total number of live oysters observed were all downriver of the Corrotoman River (Table D2 and Figure D1). Six out of the ten stations sampled had some spatfall, with an average of 1.9 spat bushel^{-1} while the other four stations sampled had zero spatfall. Upriver of the Corrotoman River (excluding Ross Rock), the make-up of oysters was approximately a 50/50 split of small and market size oysters, whereas downriver of the mouth of the Corrotoman River the oysters were predominately small, accounting for greater than 80% of the total.

The number of market oysters bushel^{-1} ranged from 8 (Middle Ground) to 30 (Broad Creek). For the second year in a row, Drumming Ground near the mouth of the Corrotoman River had the highest number of small oysters bushel^{-1} with 179. There was a notable, but small decrease in market oysters at Ross Rock, Bowler's Rock, Morattico Bar, and Middle Ground and an increase at Hog House when compared with 2002 numbers (Figures D9, D10A, and D10B). The number of market oysters at Broad Creek has remained relatively steady since about 1994 (Figure D10B). There was a slight increase in the number of small oysters during 2003 at Smokey Point and Hog House, and relatively no change at any of the other eight bars sampled. When compared with 2002 there was a large decrease in the number of spat at all ten bars sampled in the system. Settlement at the five most upriver stations, while low during 2003, was typical for those sites (historically characterized by low spatfall), whereas settlement at the five most downriver stations (which are historically higher) was the lowest observed during the past fifteen years of monitoring (Figure D10A and D10B).

The total number of boxes bushel^{-1} ranged from 12 (Hog House and Long Rock) to 68 (Broad Creek). At seven out of the ten stations sampled, greater than 25% of the total (live and dead) were boxes. Of these the majority of them were old boxes except at Broad Creek, which had a disproportionate number of new boxes when compared with the other sites sampled. There were no spat boxes observed in any of the samples.

Water temperature on the days of sampling ranged from 18 to 20°C. Salinity increased moving from the most upriver station (Ross Rock: 6 ppt) toward the mouth (Broad Creek: 13 ppt).

Great Wicomico River

The total number of live oysters bushel^{-1} in the Great Wicomico River was low averaging 98 (Whaley's East), 111 (Fleet Point), and 338 (Haynie Point). The live oysters found were predominately small (greater than 67%) at all three stations sampled. There was a notable increase in the number of market and small oysters at Whaley's East and an increase in small oysters at Haynie Point when compared with 2002 numbers (Figures D11 and D12). There was a small, but notable decrease in the number of market size oysters at Haynie Point and a substantial decrease in the number of spat at all three stations. Settlement in the Great Wicomico River was moderate compared with that observed over the past fifteen years (Figure D12). Boxes made up 5 (Haynie Point) to 15% (Fleet Point) of the total (live and dead) oysters counted. This was approximately a 50/50 split of new and old boxes, with a slightly higher percentage of old boxes present. There were only a few spat boxes observed and of these none appeared to have drill holes (indicative of oyster drills). Water temperature was between 19 and 20°C and salinity was 13 ppt on the day of sampling.

DISCUSSION

The abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the turn of the century (Hargis and Havens, 1995). In recent years the greatest concentration of market oysters on Virginia public grounds has been found at the upper limits of oyster distribution (lower salinity areas) in the James River and Rappahannock River, with the exclusion of Broad Creek in the mouth of the Rappahannock River. Presently, the abundance of market oysters in the Virginia tributaries of the Chesapeake remains low (mean of 11 market oysters $bushel^{-1}$).

As seen in most recent years, the bulk of Virginia's oyster population was composed primarily of small oysters. Except for the two stations in Mobjack Bay and three in the Rappahannock River, greater than 65% of the total number of oysters observed consisted of small oysters. Overall oyster recruitment was poor throughout the bay especially when compared with 2002 recruitment values. Tow Stake in the Mobjack Bay, which in recent years has been characterized with low recruitment levels showed the highest number of spat during 2003.

Historically oyster demographics in the James River showed a downstream trend where the number of spat increased while the number of small oysters decreased. Circulation in the system is such that oyster larvae from the upper limits of oyster abundance (lower salinity areas) are flushed further down river to set at the higher salinity sites (Haven and Fritz, 1985). Given the extremely low salinities at the upriver oyster bars during 2003, this pattern was not expressed as clearly as in years past. The largest number of small oysters were found at Horsehead and in the Burwell Bay area (Figure D1) and the few spat that were observed were found in Burwell Bay and downriver.

As discussed in the 2002 annual report (Southworth et al., 2003) caution must be used when interpreting fall dredge spatfall data. Given the high number of spat observed during 2002, we expected to see a relatively large increase in small oysters during 2003. We did in fact observe this at the majority of the sites in the James, Piankatank, and Great Wicomico Rivers. The one site where a large decrease in the number of small oysters was observed was Deep Water Shoals. This decrease was coupled with a two-fold increase in the number of boxes, which can most likely be attributed to low salinities at this site throughout most of the year.

Spatfall during 2003 was low throughout the James, York, Piankatank, and Rappahannock Rivers, with an average of 4.6 spat $bushel^{-1}$. In all four river systems, spatfall was among the lowest observed during the past fifteen years of monitoring. This was most likely caused by a combination of the high amount of rainfall observed throughout the year and Hurricane Isabel which entered the Bay on September 18, 2003, causing low salinities throughout most of the season (VIMS Ferry Pier Data). Increased rainfall and subsequent run-off is especially apparent and the effect is much greater in the larger systems like the James, York, and Rappahannock Rivers. Settlement at Tow Stake in the Mobjack Bay and at all three stations in the Great Wicomico River was moderate especially compared to the other four systems. Settlement at Tow Stake was among the highest observed over the past fifteen years despite an apparent lack of broodstock oysters in the system. This can most likely be attributed to a broodstock source located elsewhere in the system.

The number of boxes observed during 2003, while lower at most sites than 2002 numbers, was still relatively high. As discussed in the first part of this report, 2002 was characterized by higher than normal salinity whereas 2003 was characterized by a lower than normal salinity. Given that disease prevalence tends to increase as salinity increases (Calvo and Burreson, 2000), disease was most likely the reason behind the large number of boxes during 2002. Low salinities, while good for purging MSX (Haskin and Ford, 1982) and suppressing Dermo (Burreson and Andrews, 1988) from the oysters can often be detrimental in and of themselves. When coupled with temperatures greater than 23°C, high mortality of oysters occurs at salinities at or below 5 ppt (Loosanoff, 1952). Salinities in the upper part of the James River were quite low throughout most of the season (less than 11 ppt), while temperatures were average (greater than 25°C; Part I of this report). Given that the James, York, and Rappahannock Rivers are all large watersheds that experience high run-off (http://www.chesapeakebay.net/wshed.htm), it would stand to reason that low salinity was the cause of most of the mortality observed during 2003. This effect would be especially apparent in the upper reaches of the tributaries, where there were several weeks in which the salinity was zero and the water temperature was in the mid to high twenties.

There were very few spat boxes found at any of the sites monitored, which isn't surprising given the low numbers of spat observed. At Burton Point in the Piankatank River, which has been characterized in the past several years with a high number of drill boxes (spat boxes with holes indicative of predation by oyster drills), there were no spat boxes and therefore no drill boxes. The only site with a relatively high number of spat boxes was Tow Stake in Mobjack Bay (also one of the few sites with a moderate number of spat). At Tow Stake there was an average of 16 spat boxes bushel^{-1} and, of these, five were drill boxes. In addition, there were two live spat found with the beginnings of a drill hole in them. These holes were most likely caused by the oyster drills *Urosalpinx cinera* or *Eupleura caudata* which are common in the lower Chesapeake Bay. Both of these species are voracious predators of oyster spat causing mortality throughout most of the Chesapeake Bay (Carriker, 1955) up until the occurrence of Hurricane Agnes (1972) which wiped them out in all but the lower reaches of the James River and mainstem Bay (Haven, 1974). However, individuals of both of these species and drill eggmasses have been found in recent years in the mouths of the Piankatank and Rappahannock Rivers and in Mobjack Bay including live specimens of *Eupleura caudata* at Pultz Bar and *Urosalpinx cinera* at Tow Stake during the 2003 dredge survey.

Table D1: Station locations for the VIMS Fall dredge survey.

STATION	LATITUDE	LONGITUDE
James River		
Deep Water Shoal	37 08 56	76 38 08
Mulberry Point	37 07 09	76 37 55
Horsehead	37 06 24	76 38 02
Point of Shoal	37 04 37	76 38 36
Swash	37 05 52	76 36 44
Long Shoal	37 04 35	76 37 01
Dry Shoal	37 03 41	76 36 14
Wreck Shoal	37 03 37	76 34 20
Thomas Rock	37 01 32	76 29 33
Nansemond Ridge	36 55 20	76 27 10
York River		
Bell Rock	37 29 05	76 44 58
Aberdeen Rock	37 20 00	76 36 06
Mobjack Bay		
Tow Stake	37 20 18	76 23 28
Pultz Bar	37 20 22	76 23 16
Piankatank River		
Ginney Point	37 32 00	76 24 12
Palace Bar	37 31 36	76 22 12
Burton Point	37 30 54	76 19 42
Rappahannock River		
Ross Rock	37 54 04	76 47 21
Bowler’s Rock	37 49 35	76 44 08
Long Rock	37 48 59	76 42 50
Morattico Bar	37 46 55	76 39 33
Smokey Point	37 43 07	76 34 48
Hog House	37 38 30	76 33 04
Middle Ground	37 41 00	76 28 24
Drumming Ground	37 38 38	76 27 59
Parrot Rock	37 36 21	76 25 20
Broad Creek	37 34 37	76 18 03
Great Wicomico River		
Haynie Point	37 49 47	76 18 33
Whaley’s East	37 48 31	76 18 00
Fleet Point	37 48 35	76 17 19

Table D2: Results of the Virginia public oyster grounds survey, Fall 2003.York River station numbers (*) are based on two 1 bushel samples. Note that the bushel measure used is a Virginia bushel which is equivalent to 3003.9 cubic inches. A Virginia bushel differs in volume from both a U.S. bushel (2150.4 cubic inches) and a Maryland bushel (2800.7 cubic inches). "**" indicates a private bar. Middle Ground (#) is located in the Corrotoman River, a subestuary of the Rappahannock River system.

Station	Date	Water temp. (°C)	Salinity (ppt)	Average number of oysters per bushel				Average number of boxes per bushel			
				Market	Small	Spat	Total	New	Old	Spat	Total
James River											
Deep Water Shoal	10/24	16.5	7.0	0	147.0	0	147.0	91.5	220.0	0	311.5
Mulberry Point	10/24	16.5	10.0	6.0	589.5	0	595.5	216.0	122.5	0	338.5
Horsehead	10/24	16.5	10.0	9.5	977.5	1.0	988.0	76.0	71.5	0	147.5
Point of Shoal	10/24	16.5	9.0	20.5	354.0	2.0	376.5	79.5	56.0	2.5	138.0
Swash	10/24	16.5	12.0	8.5	501.5	0	510.0	28.0	48.5	0	76.5
Long Shoal	10/24	16.0	12.0	24.5	501.5	11.5	537.5	25.5	70.5	0.5	96.5
Dry Shoal	10/24	16.0	11.0	8.5	148.5	23.5	180.5	15.5	37.5	0	53.0
Wreck Shoal	10/24	16.0	14.0	5.0	316.5	32.5	354.0	13.5	18.5	1.5	33.5
Thomas Rock	10/23	17.0	15.0	3.5	143.5	11.0	158.0	4.5	14.5	0	19.0
Nansemond Ridge	10/23	17.0	13.0	12.5	65.5	13.0	91.0	1.0	10.5	0.5	12.0
York River*											
Bell Rock **	10/22	18.0	13.0	3.0	186.5	0	189.5	6.5	20.5	0	27.0
Aberdeen Rock	10/22	18.5	17.0	3.5	61.0	0.5	65.0	7.0	9.5	0	16.5
Mobjack Bay											
Tow Stake	10/17	20.0	17.0	5.0	3.0	152.0	160.0	3.0	8.0	16.0	27.0
Pultz Bar	10/17	20.0	17.0	3.5	0	1.0	4.5	0	1.5	0	1.5
Piankatank River											
Ginney Point	10/16	20.0	11.0	7.5	112.0	3.0	122.5	7.5	35.0	0	42.5
Palace Bar	10/16	19.0	11.5	18.0	352.5	4.5	375.0	9.0	25.5	0	34.5
Burton Point	10/16	18.5	12.0	8.0	54.5	1.5	64.0	5.0	23.5	0	28.5
Rappahannock River											
Ross Rock	10/21	18.0	6.0	12.0	35.5	0	47.5	3.5	9.0	0	12.5
Bowler's Rock	10/21	18.0	9.0	12.5	7.5	0	20.0	0	13.5	0	13.5
Long Rock	10/21	18.0	9.0	12.5	11.5	0	24.0	1.0	11.0	0	12.0
Morattico Bar	10/21	18.0	10.0	14.5	28.5	1.0	44.0	1.5	25.0	0	26.5
Smokey Point	10/21	18.0	11.0	14.0	39.0	3.5	56.5	3.0	20.0	0	23.0
Hog House	10/21	18.0	13.0	21.0	12.5	0	33.5	1.0	10.5	0	11.5
Middle Ground #	10/21	18.0	12.0	8.0	85.0	1.5	94.5	11.0	50.0	0	61.0
Drumming Ground	10/21	18.0	12.0	18.0	178.5	2.0	198.5	8.0	40.5	0	48.5
Parrot Rock	10/21	20.0	13.0	15.0	81.0	2.0	98.0	5.0	15.0	0	20.0
Broad Creek	10/16	20.0	13.0	30.0	114.5	1.5	146.0	39.0	29.0	0	68.0
Great Wicomico River											
Haynie Point	10/15	20.0	13.0	1.0	235.5	101.5	338.0	6.5	18.5	2.0	27.0
Whaley's East	10/15	19.0	13.0	18.0	66.0	14.0	98.0	13.0	19.0	1.0	33.0
Fleet Point	10/15	19.5	13.0	11.5	78.0	21.5	111.0	13.5	23.0	1.5	38.0

Figure D1: Map showing the location of the oyster bars sampled during the 2003 dredge survey.

James River: 1) Deep Water Shoal, 2) Mulberry Point, 3) Horsehead, 4) Point of Shoal, 5) Swash, 6) Long Shoal, 7) Dry Shoal, 8) Wreck Shoal, 9) Thomas Rock, 10) Nansemond Ridge.

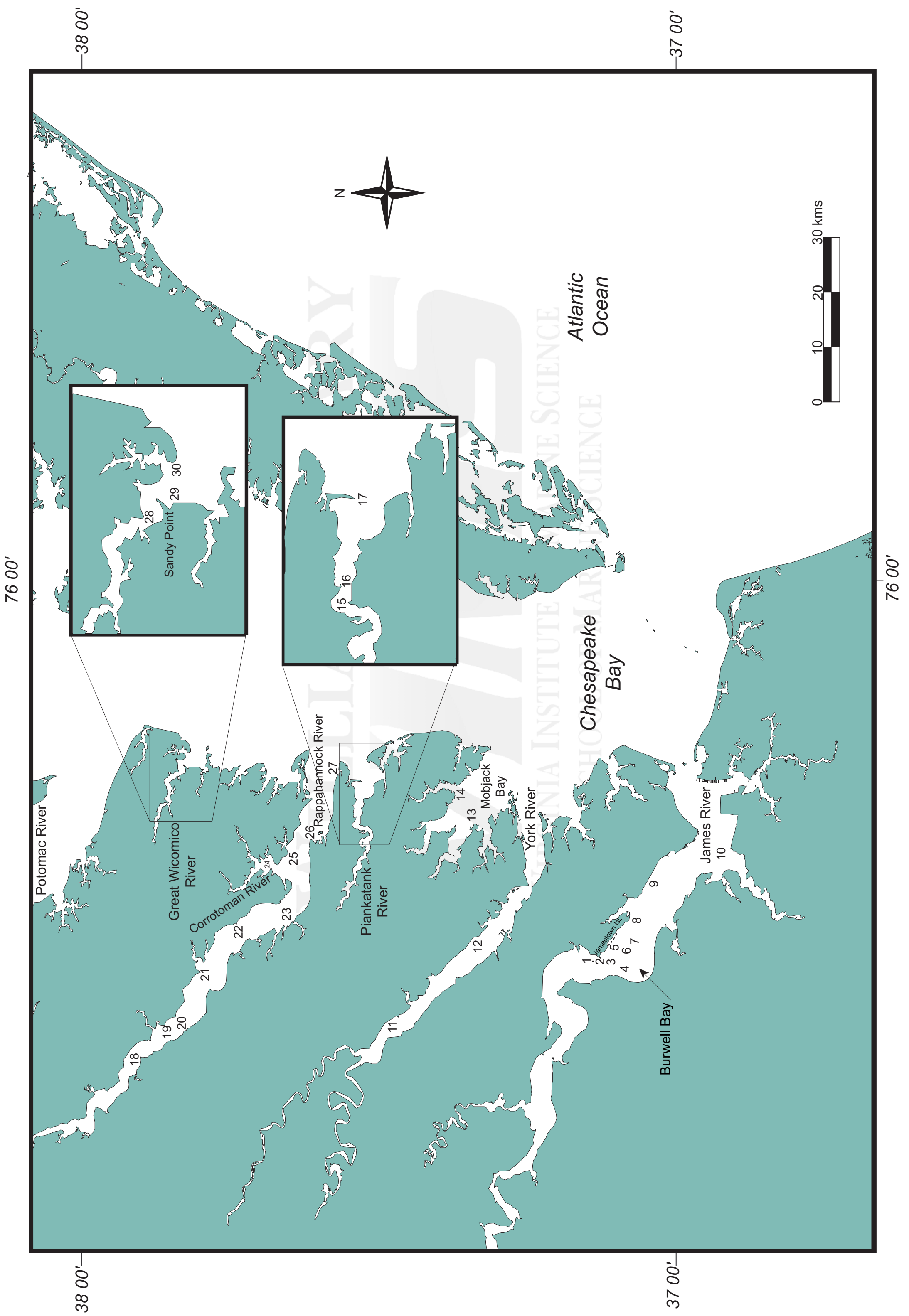
York River: 11) Bell Rock, 12) Aberdeen Rock.

Mobjack Bay: 13) Tow Stake, 14) Pultz Bar.

Piankatank River: 15) Ginney Point, 16) Palace Bar, 17) Burton Point.

Rappahannock River: 18) Ross Rock, 19) Bowler's Rock, 20) Long Rock, 21) Morattico Bar, 22) Smokey Point, 23) Hog House, 24) Middle Ground, 25) Drumming Ground, 26) Parrot Rock, 27) Broad Creek.

Great Wicomico River: 28) Haynie Point, 29) Whaley's East, 30) Fleet Point.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Chesapeake Bay
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Burwell Bay
Sandy Point
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Figure D2: Map showing the location of the artificial oyster reefs in the Virginia portion of the Chesapeake Bay.

Lynnhaven River: 1) Eastern Branch Reef, 2) Humes Marsh Reef, 3) Long Creek Reef, 4) Broad Bay Reef.

Lafayette River: 5) Hampton Boulevard Bridge Reef, 6) Tanner's Point Reef.

Elizabeth River: 7) Western Branch Reef, 8) Craney Island Reef, 9) Ford Plant Reef, 10) Deep Creek Reef, 11) Gilmerton Reef, 12) Port Authority Reef.

Back River: 13) Langley Reef.

York River: 14) Felgate's Creek Reef, 15) Amoco Reef.

Mobjack Bay: 16) Ware River Reef, 17) North River Reef, 18) East River Reef.

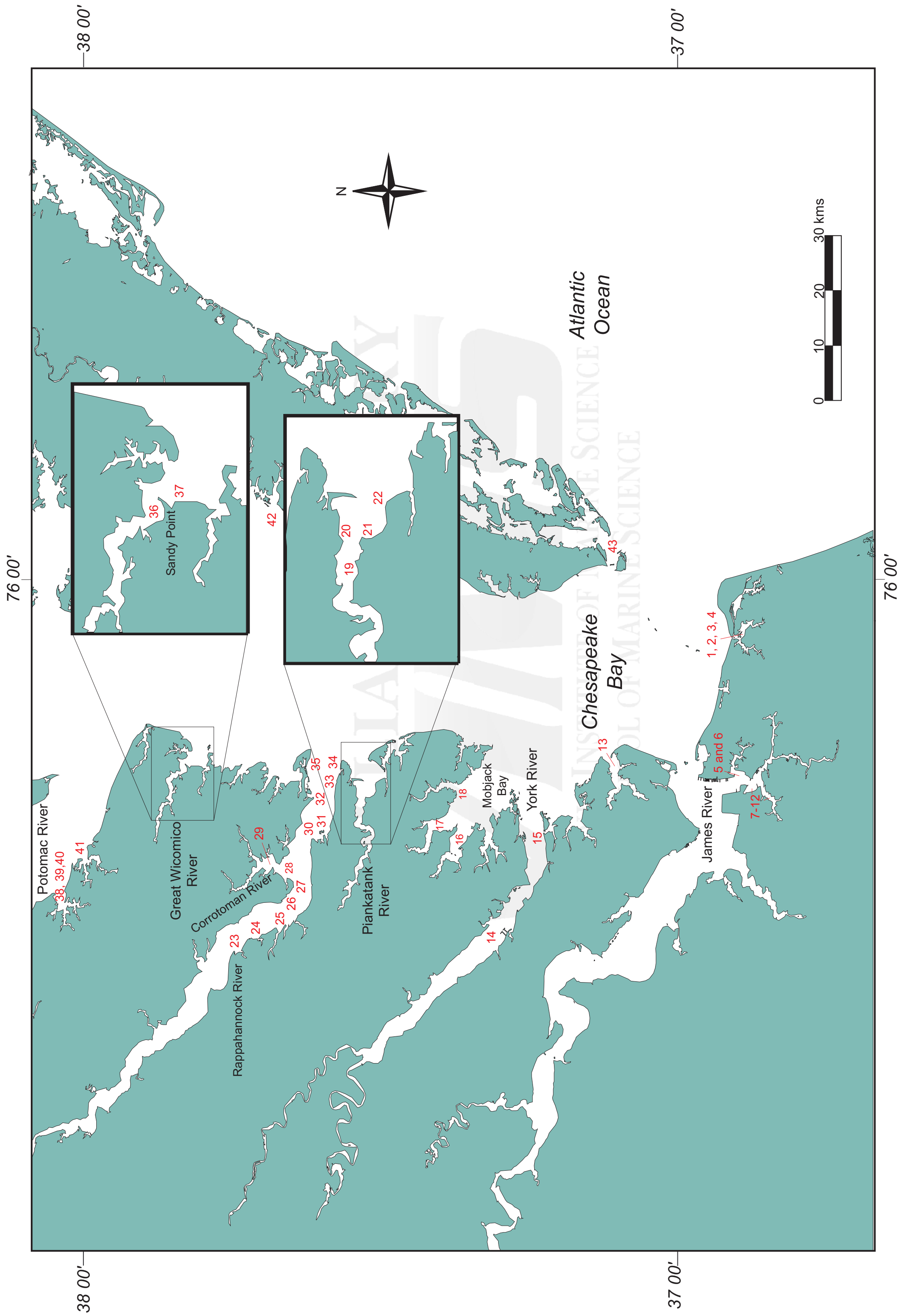
Piankatank River: 19) Palace Bar Reef, 20) Bland Point Reef, 21) Iron Point Reef, 22) Burton Point Reef.

Rappahannock River: 23) Upper Waterview Reef, 24) Weeks Reef, 25) Lagrange Creek Reef, 26) Towles Point Reef, 27) Temple Bay Reef, 28) Drumming Ground Reef, 29) Ferry Bar Reef, 30) Parrot's Rock Reef, 31) Mill Creek Reef, 32) Mosquito Point Reef, 33) Sturgeon Bar Reef, 34) Broad Creek Reef, 35) Butler's Hole Reef.

Great Wicomico River: 36) Shell Bar Reef, 37) Cranes Creek Reef.

Potomac River: 38) Indian Bar Reef, 39) Kinsale Point Reef, 40) Crow Bar Reef, 41) Coan River Reef.

Eastern Shore: 42) Pungoteague Creek Reef, 43) Fishermen Island Reefs.



38 00'
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Potomac River
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Great Wicomico
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Sandy Point
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Corrotoman River
Rappahannock River
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Piankatank
River
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York River
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43
1, 2, 3, 4
James River
5 and 6
7-12

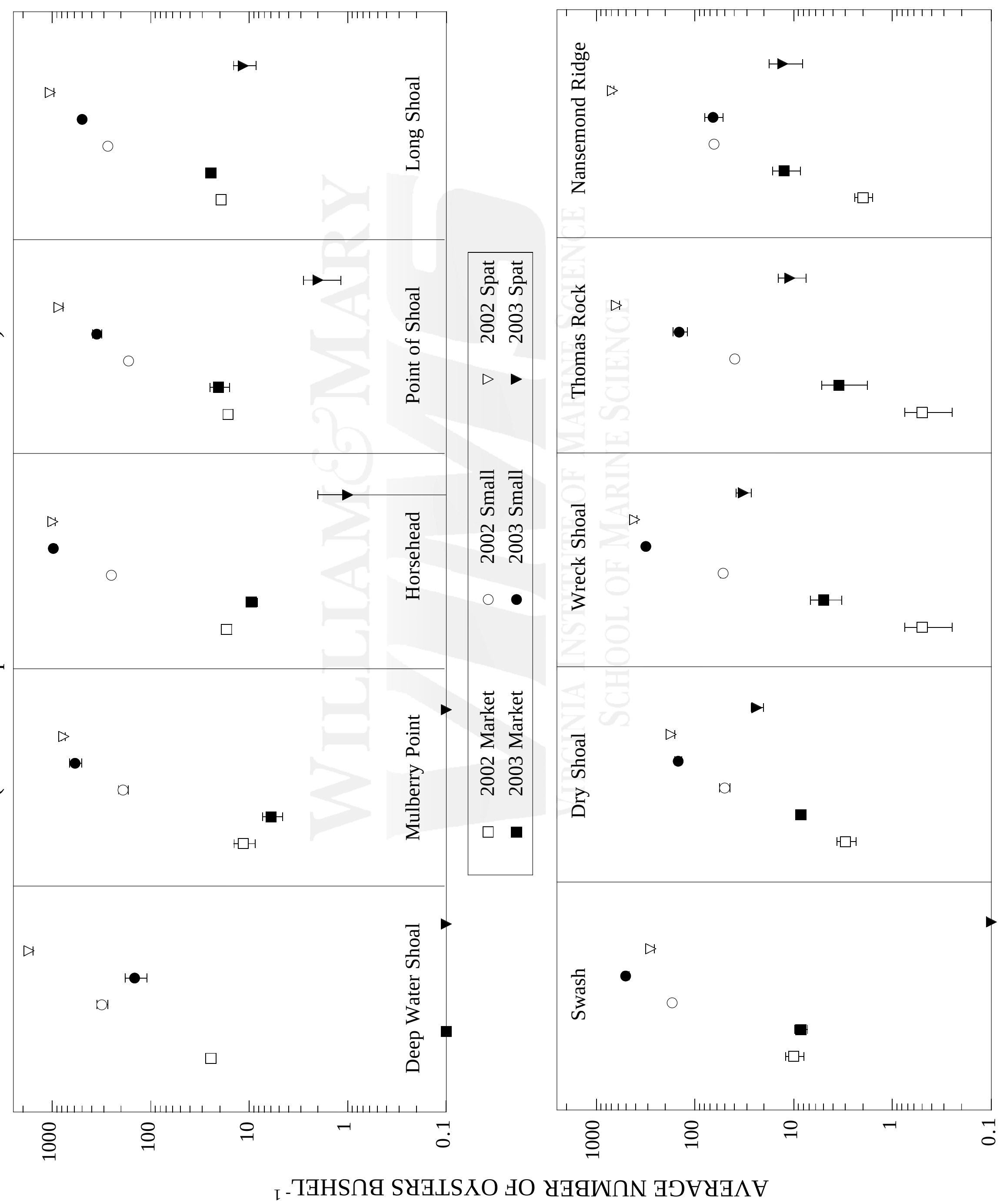


FIGURE D3: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE JAMES RIVER (2002-2003)
(error bars represent standard error of the mean)

FIGURE D4A: JAMES RIVER OYSTER TRENDS OVER THE PAST
15 YEARS (10 WHERE DATA IS NOT AVAILABLE)
(error bars represent standard error of the mean)

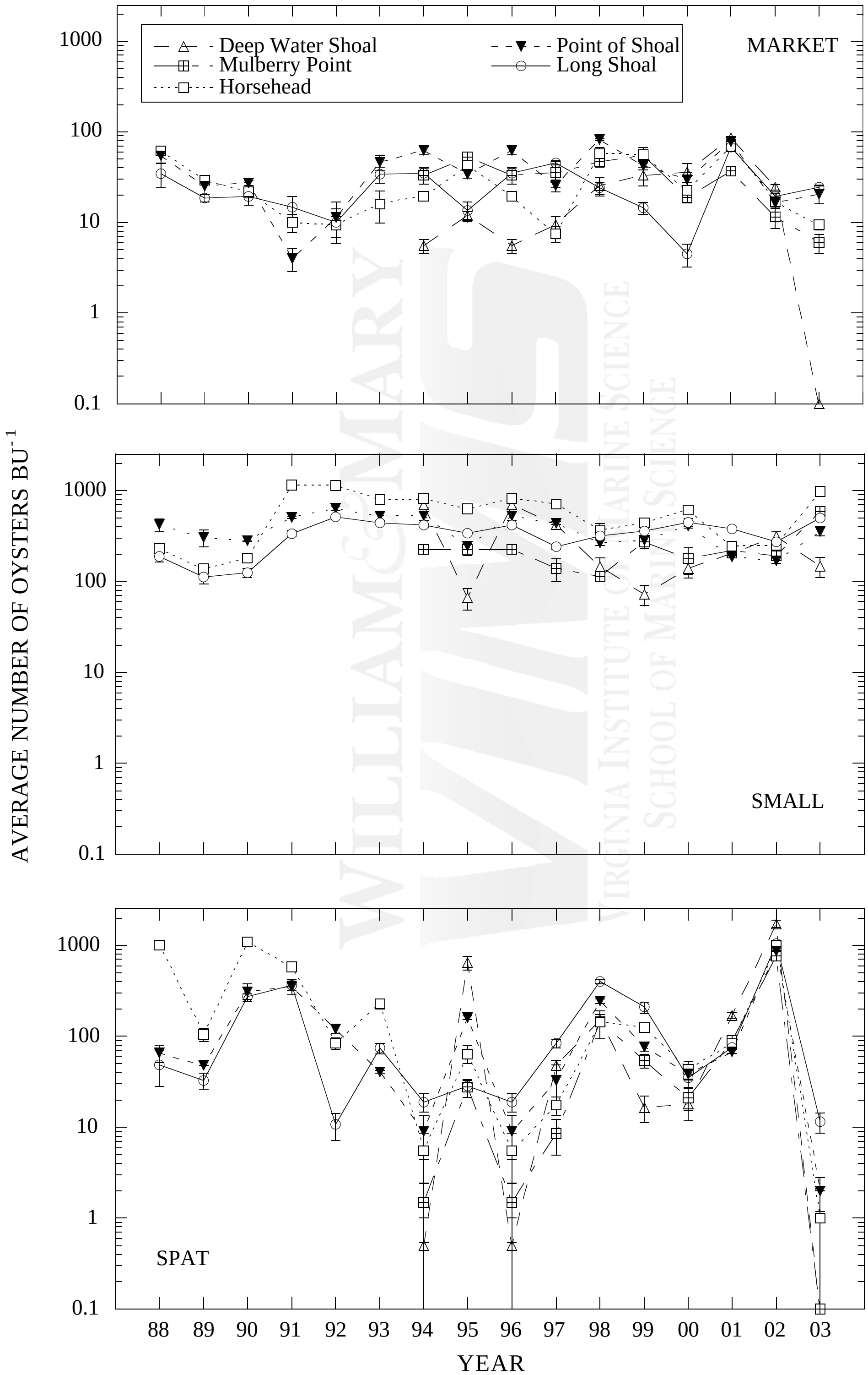


FIGURE D4B: JAMES RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)

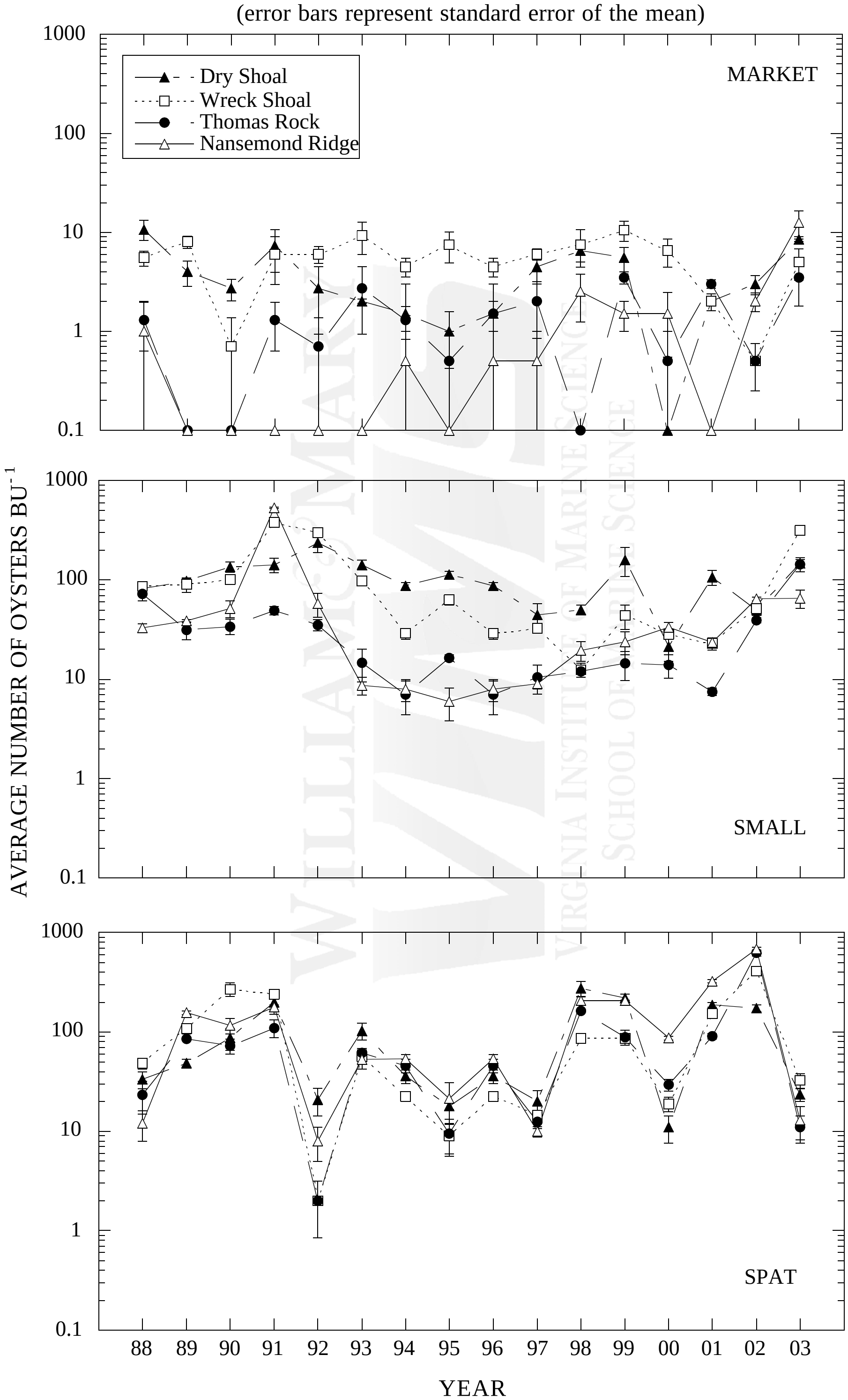


FIGURE D5: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE YORK RIVER AND MOBJACK BAY (2002-2003)
(error bars represent standard error of the mean)

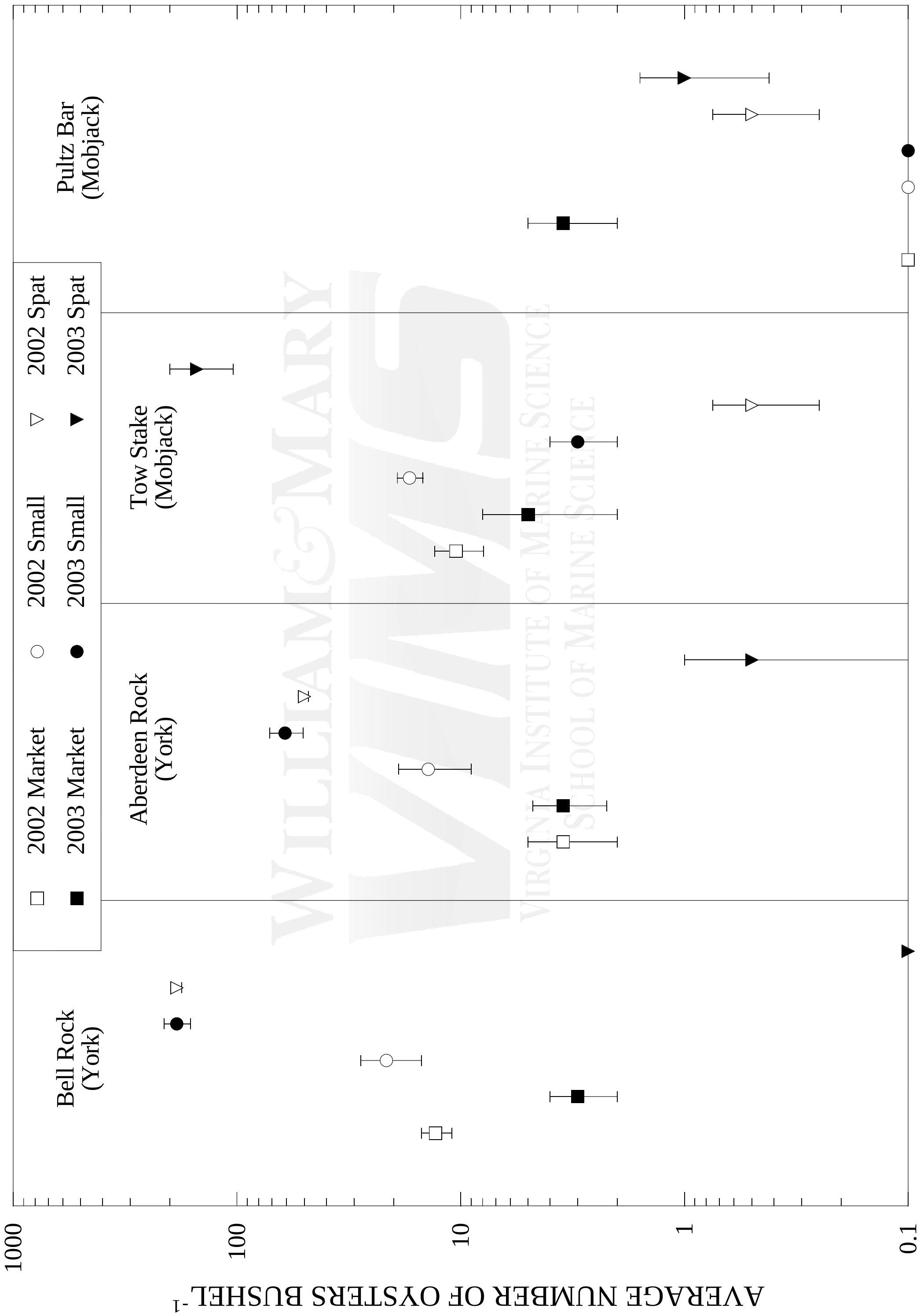


FIGURE D6: YORK RIVER AND MOBJACK BAY OYSTER TRENDS OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)

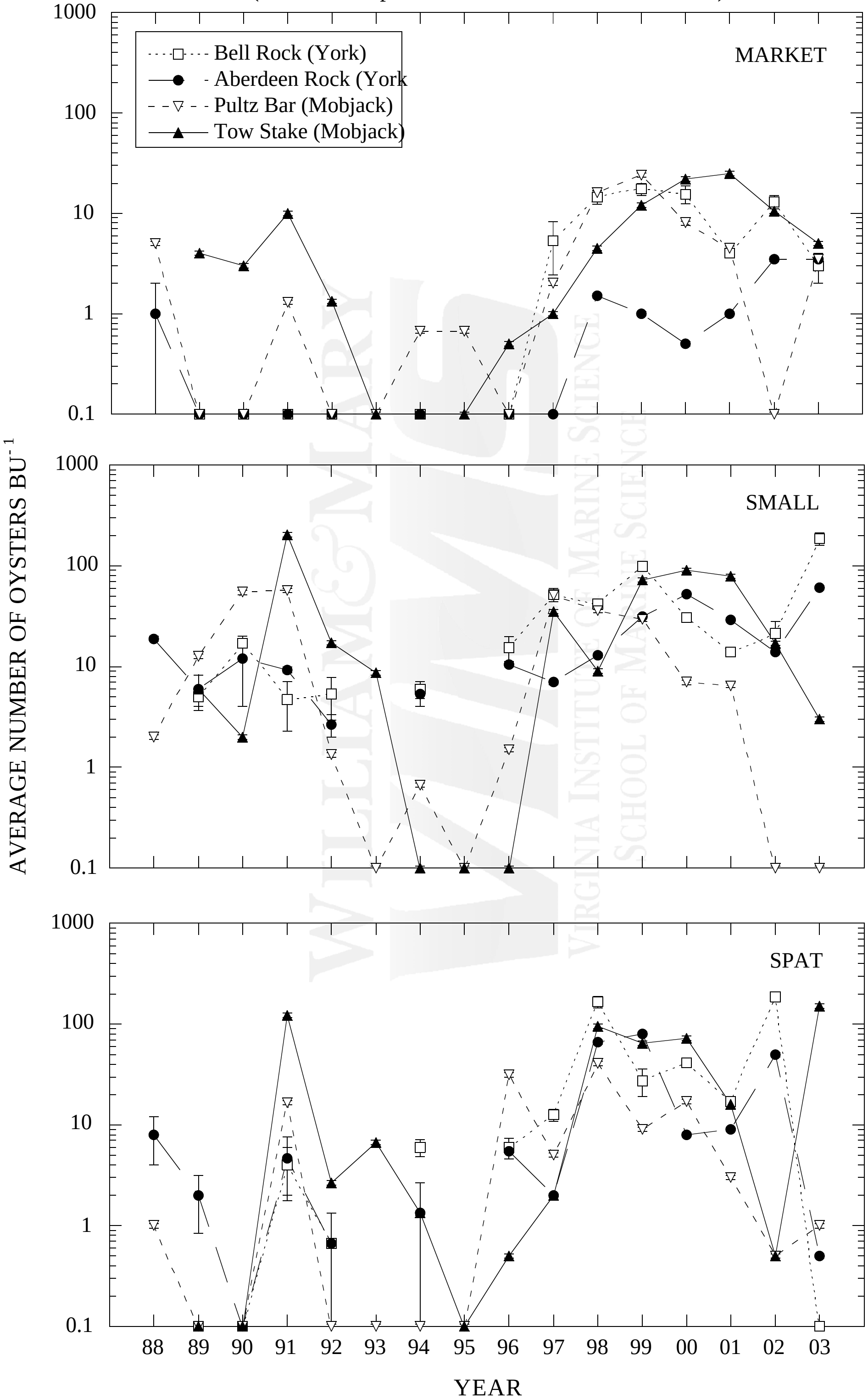


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE PIANKATANK RIVER (2002-2003)
(error bars represent standard error of the mean)

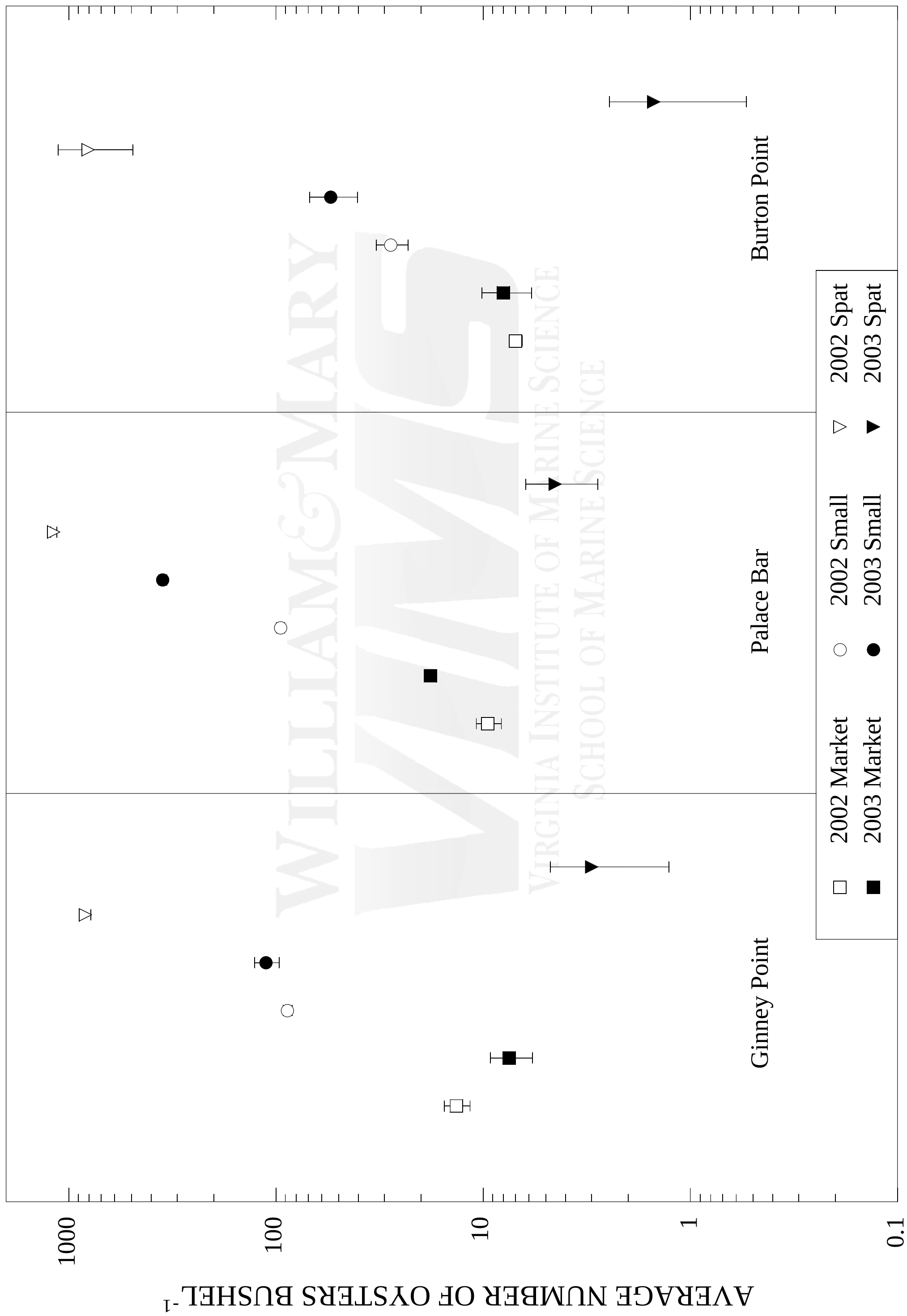


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)

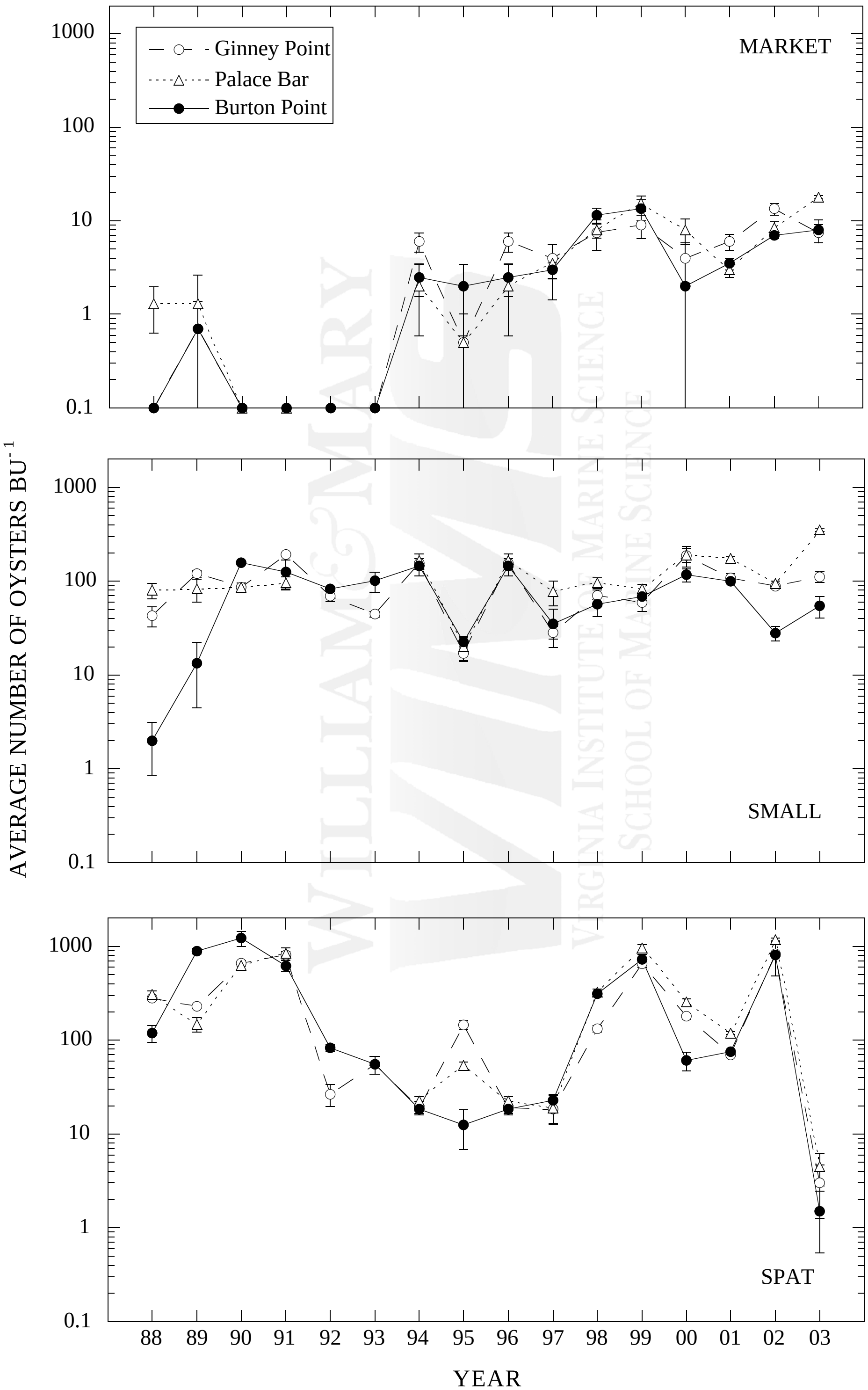


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2002-2003)
(error bars represent standard error of the mean)

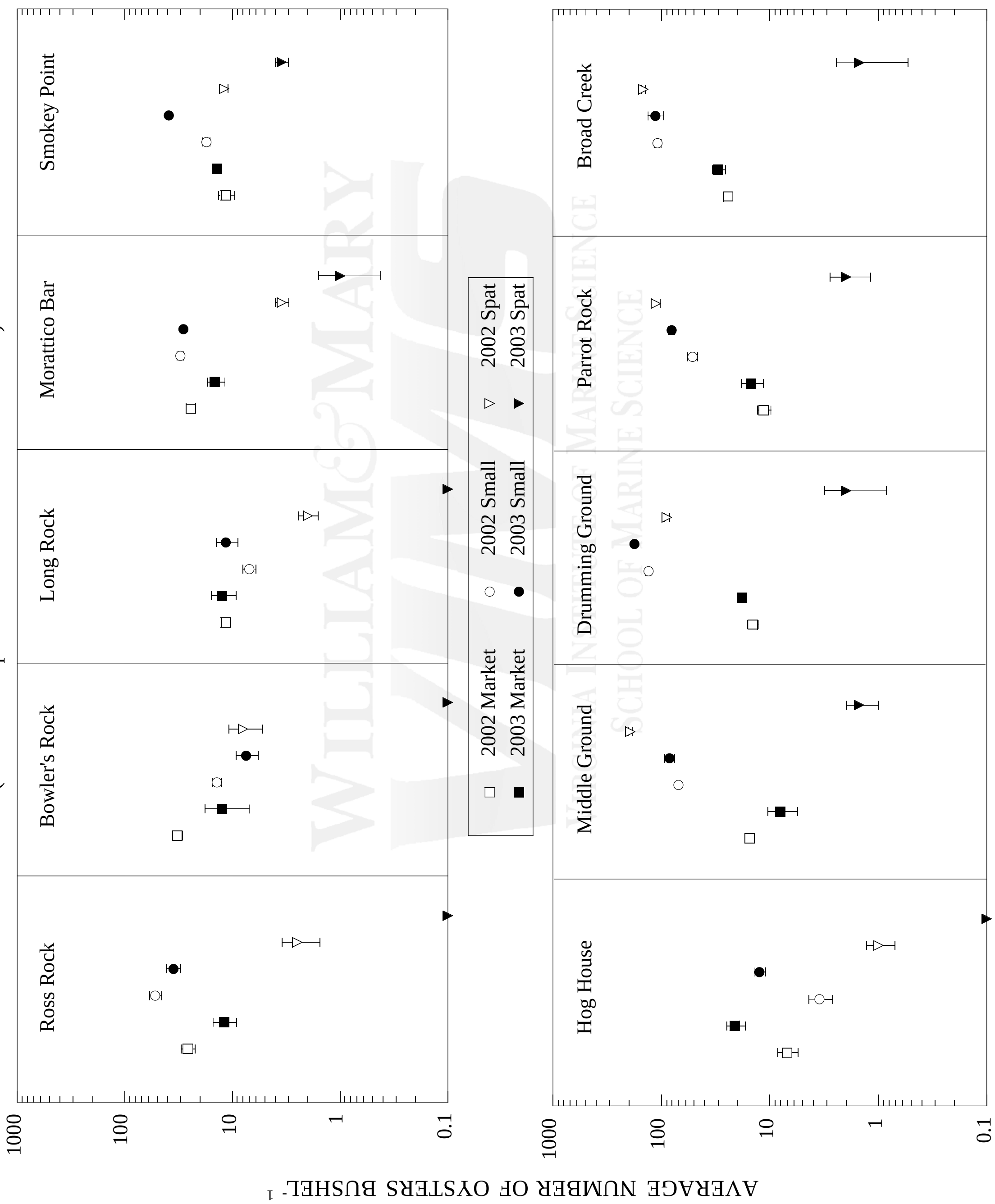


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)

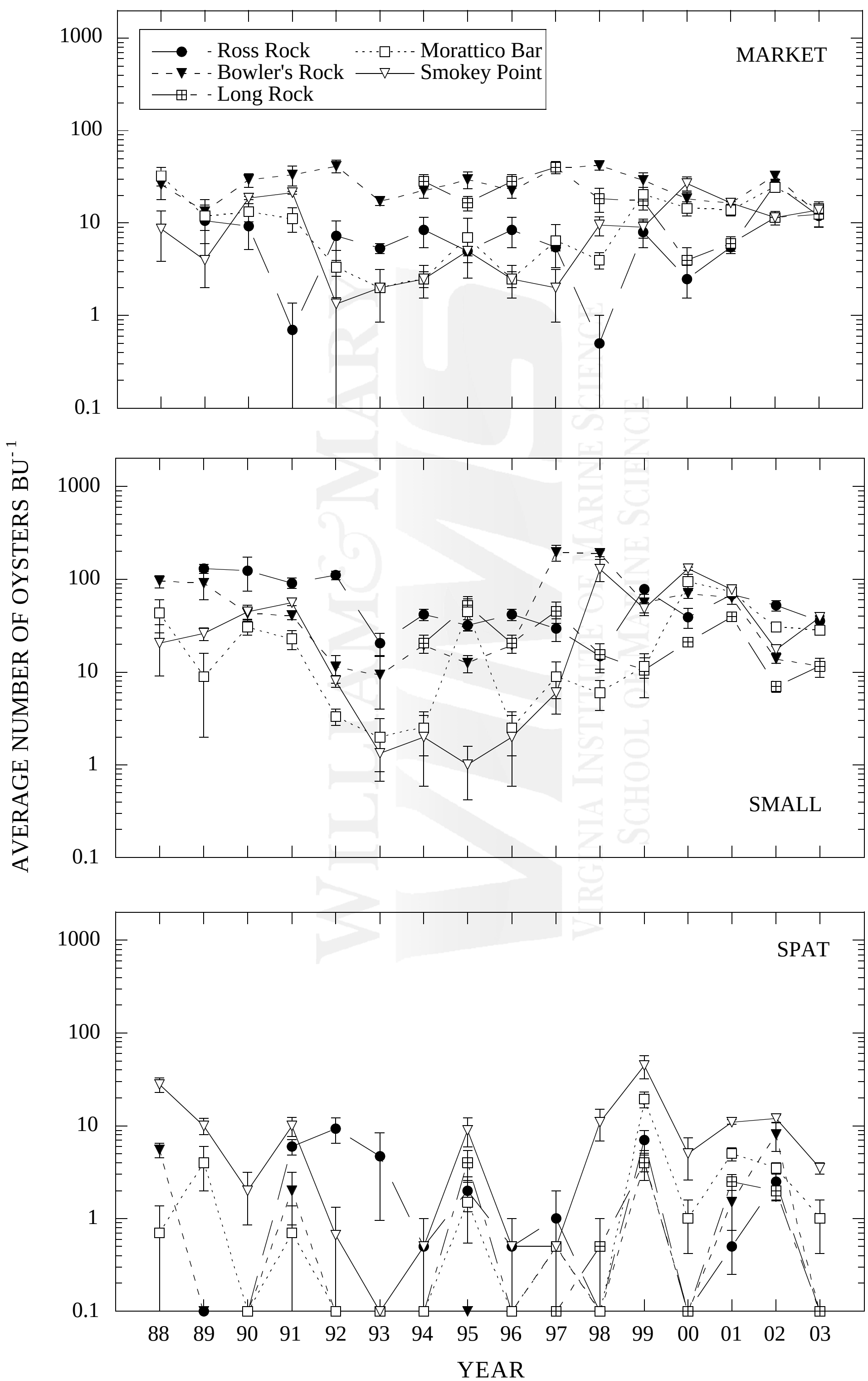


FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)

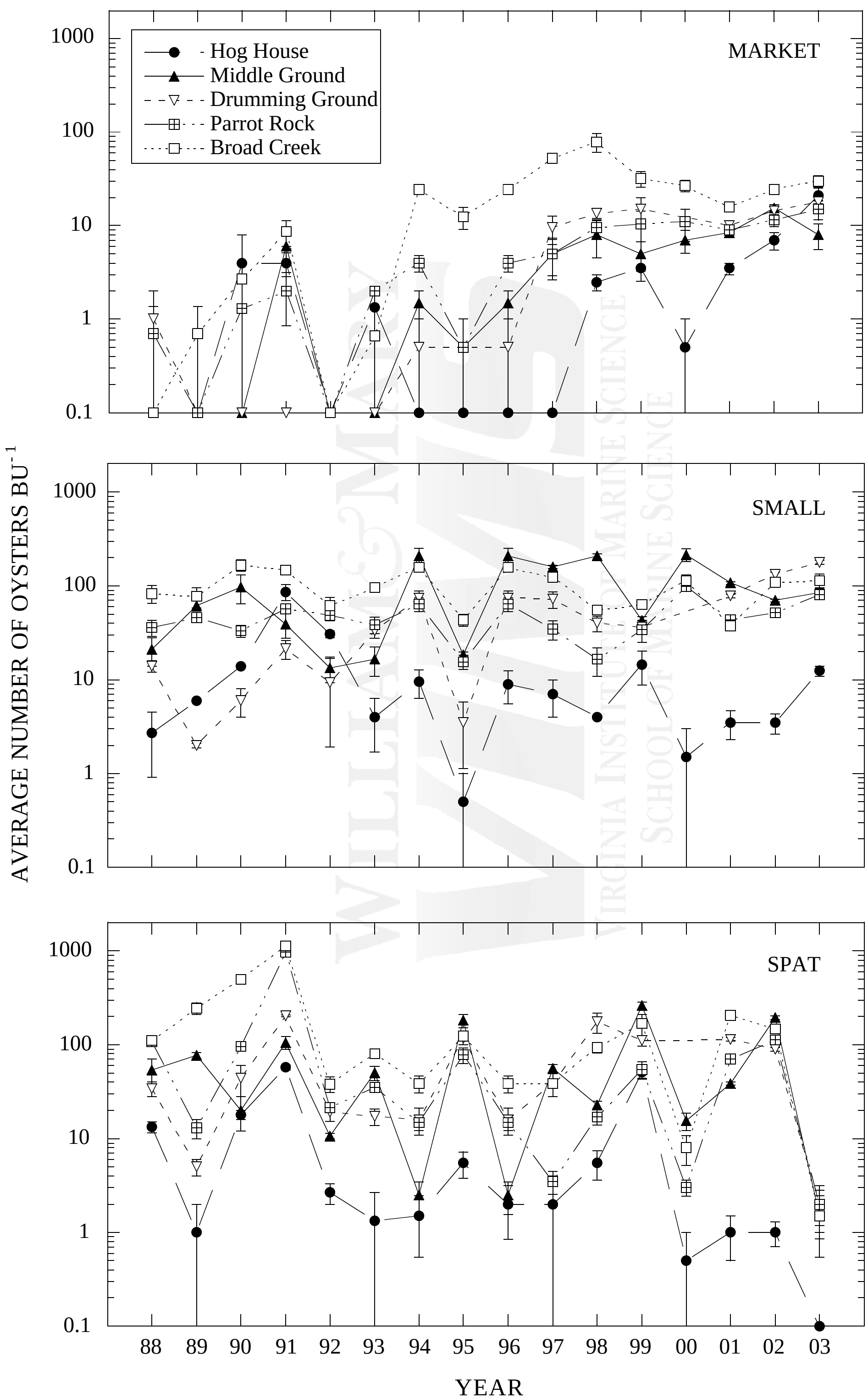


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE GREAT WICOMICO RIVER (2002-2003)
(error bars represent standard error of the mean)

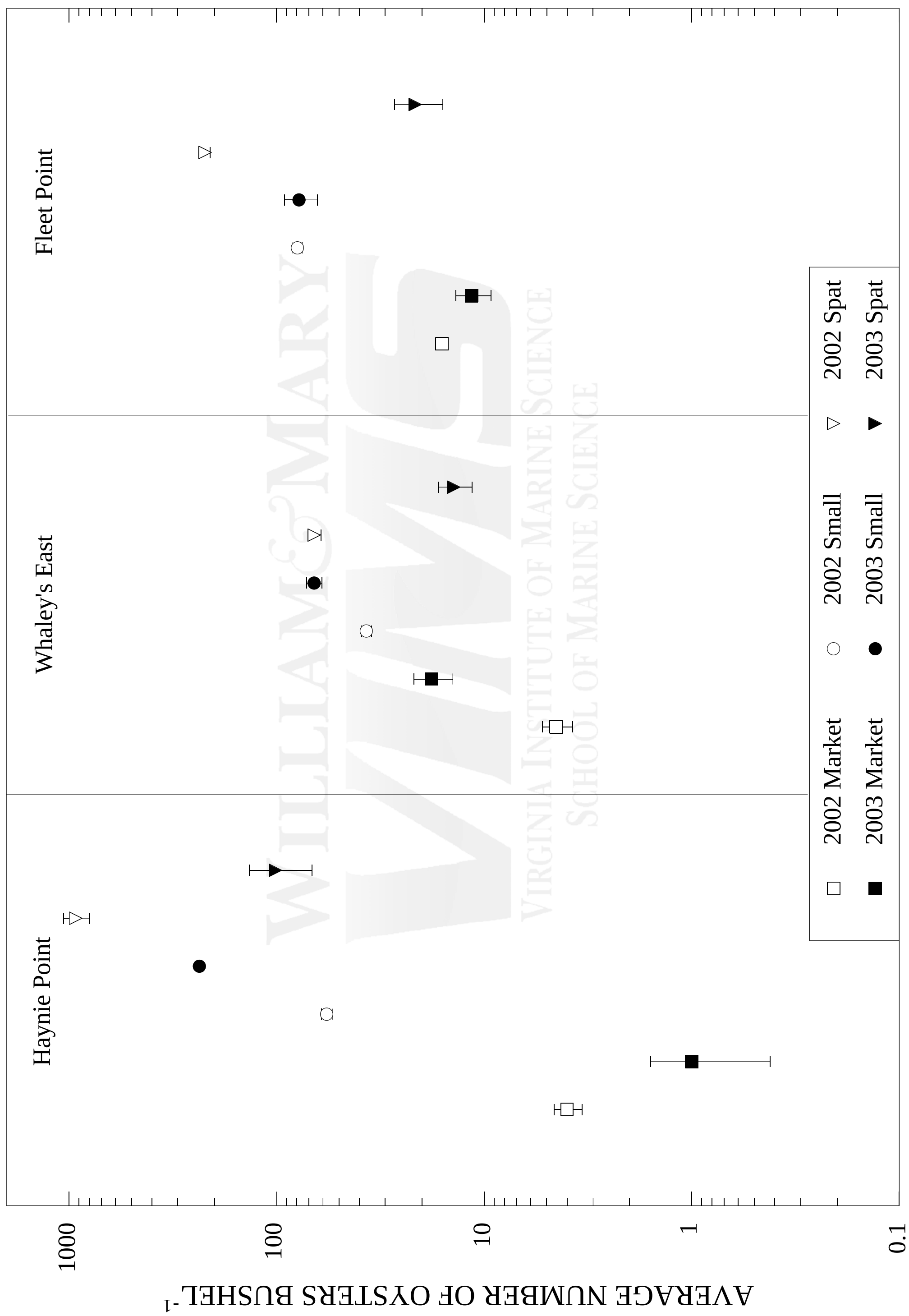
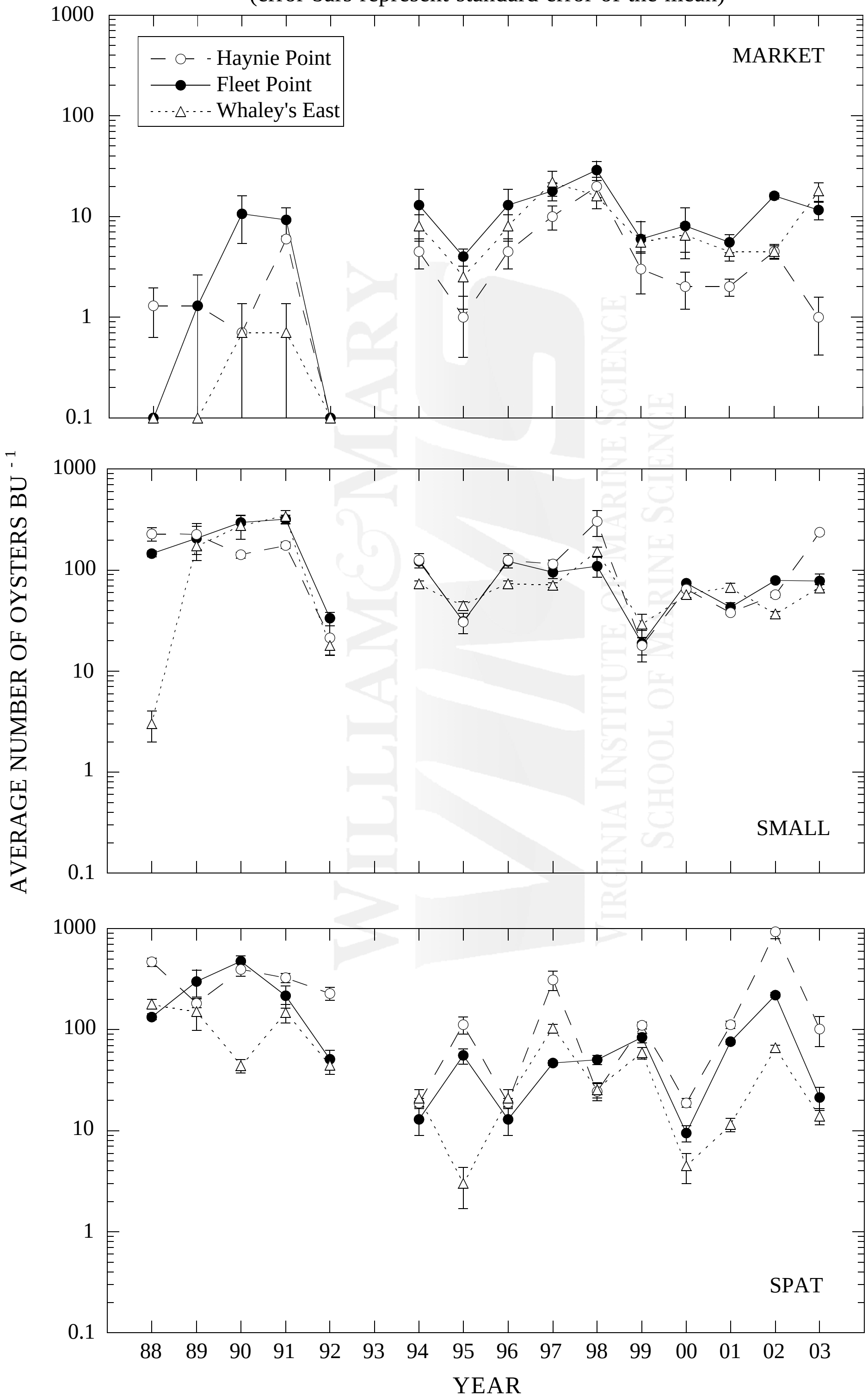


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(error bars represent standard error of the mean)



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